Tri-Lakes Watershed Feasibility Study

JUNE, 1992

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TRI-LAKES

FEASIBILITY STUDY

June 1, 1992

Submitted to:

TRI-LAKES PROPERTY OWNERS ASSOCIATION
WHITLEY COUNTY, INDIANA

Submitted by:

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CONTENTS

LIST OF FIGURES

Round Lake

Shriner Lake

Watershed

LIST OF TABLES

Cedar Lake

Round Lake

Shriner Lake

Watershed

FOREWORD

AUSPICES

The "Tri-Lakes Watershed Feasibility Study" was authorized by the Tri-Lakes Property Owners Association. Funding for the study was provided by the Tri-Lakes Property Owners Association under a grant from the "T by 2000" Lake Enhancement Program of the Indiana Department of Natural Resources, Division of Soil Conservation.

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The long enduring patience of the Lake Enhancement Staff is appreciated.

EXECUTIVE SUMMARY

INTRODUCTION

Gensic & Associates and Thomas Crisman, Ph.D., have provided professional services to the Tri-Lakes Property Owners Association in conducting a feasibility study of the restoration of the Tri-Lakes Watershed. The study was funded by the Tri-Lakes Property Owners Association with the aid of a grant from the "T by 2000" Lake Enhancement Program of the Indiana Department of natural Resources, Division of Soil Conservation.

Members of the Property Owners Association have become increasingly concerned with the perceived deterioration of water quality in the lakes. Principal areas of concern include poor runoff water quality in inflowing streams, shoaling at stream inlets, and increased weed concentrations and algal blooms. The growing environmental awareness of local residents, and the desire to reverse the causes of cultural eutrophication were primary factors for the authorization of the study.

The principal objectives of the study were fourfold:

1. Map the Tri-Lakes Watershed and its principal drainage courses and subwatersheds.

2. Map land use and Highly Erodible Soils in the watershed and identify areas of concern which may pose a threat to the health of the lake system.

3. Assess the historical and current conditions of the lakes and establish baseline data for the continued assessment of lake water quality.

4. Provide information and develop recommendations to assist the Tri-Lakes Property Owners Association in the management of their watershed and lakes system.

WATERSHED

The Tri-Lakes Watershed is located primarily in Whitley County, Indiana and contains an area of approximately 2170 acres. The Watershed consists of 1770 acres of land and its four principal lakes, Cedar, Little Cedar, Round, and Shriner have a surface area of nearly 400 acres.

Problems in the Tri-Lakes Watershed result from both natural topographic characteristics and current land use. The watershed contains 1100 acres of Highly Erodible Land amounting to approximately 60 percent of the watershed land area. Agricultural land comprises over 50 percent of the watershed area and more than 250 acres of HEL are currently used as cropland. Over 20 percent of the watershed is developed, principally in the lake shoreline areas. These shoreline areas comprise over 25 percent of the watershed land area and are at least 55 percent Highly Erodible Land.

The upper watershed is drained by 19 principal intermittent drainage courses. Drainage course channel gradients are severe and channel erosion is a serious problem during peak runoff flows. A number of drainage channels have formed ravines adjacent to the lakes and sediment shoals in the lakes.

Water quality was sampled from selected inflowing drainage courses after a storm event. Results of laboratory analysis indicate high values for suspended solids particularly in the larger subwatersheds where land use is dominated by agriculture. Analysis of discharge from a storm sewer draining a developed shoreline area also indicated a high concentration of suspended solids.

Fifteen acre Shriner Lake 2 Subwatershed discharged runoff with by far the highest concentration of contaminants. Little Cedar Lake 2 Subwatershed which contains 394 acres is the single largest subwatershed and discharged runoff with the second highest contaminant concentration. Little Cedar Lake 2, Shriner lake 2, Round Lake 1, and Catfish Lake 1 Subwatersheds comprise 45 percent of the land area of the Tri-Lakes Watershed and runoff from these subwatersheds contained the highest concentrations of contaminants.

The principal sources of sediment and nutrient contamination of runoff water in the Tri-Lakes Watershed include:

1. High peak storm flows causing ravine and stream channel erosion. High peak storm flows are caused in part by lack of vegetative cover on agricultural lands and the drainage of wetlands which historically provided stormwater detention.

2. Erosion on individual fields due to agricultural cropping practices on Highly Erodible Lands.

3. Erosion due to construction and developed area land use practices in lake shoreline areas.

The Tri-Lakes watershed contains twenty five separate subwatersheds and drainage areas, with no single subwatershed larger than 25 percent of the entire watershed system. Recommendations are presented to address problems throughout the Tri-Lakes Watershed. No single subwatershed should be targeted as the major source of water quality problems without recognizing the cumulative effects of the other subwatersheds and areas.

Watershed recommendations include:

1. Socio-political actions by the Tri-Lakes Property Owners Association to better enable the organization to deal with environmental and lake and watershed management issues.

2. Implementation of best management practices in both the agricultural areas and developed lake shoreline areas of the watershed.

3. Restoration or construction of wetland areas or construction of detention ponds in the watershed to reduce peak runoff flows and alleviate stream channel erosion.

4. Construction of sediment basins at ravine outlets where upland detention is not feasible.

LAKES

Water quality in Big Cedar appears to have changed little since the early 1970's and the lake is still assigned to Class I, the category of best water quality. Although the historical record is sparse, water quality is poorer in Little Cedar and the lake is assigned to the category of intermediate water quality, Class II. Aquatic macrophytes have never been considered problematic in either lake, but algal blooms dominated by blue-green algae are common in Little Cedar. Ciscos, a common cold water fish in 1954, were considered rare by 1975 and extirpated by 1988. The major period of eutrophication in Big Cedar appears to have been prior to the early 1930's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters appear to have changed little since that time. Little Cedar, however, has shown a progressive increase in the annual accumulation rates of both inorganic sediments and total phosphorus since the time of land clearance in the 1800's, attesting to progressive eutrophication of the basin since European settlement.

Water quality in Round Lake appears to have changed little since the early 1970's. While the lake was assigned to Class II, the category of intermediate water quality, in the 1970's, it was assigned to the category of best water quality, Class I, in 1990. The six point difference in the eutrophication index between the two sampling periods is considered insignificant and likely associated with a change in the extent of aquatic macrophytes in the basin and variability in sampling and weather patterns between years. Aquatic macrophytes have been considered problematic since at least 1968, and algal blooms dominated by blue-green algae are common. Ciscos, a rare cold water fish in 1954, were considered extirpated by 1974. The major period of eutrophication in Round Lake appears to have been during the period from the 1910's through the early 1930's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters appear to have changed little since that time.

Water quality in Shriner Lake appears to have changed somewhat since the early 1970's. While the lake was assigned to Class I, the category of best water quality, in the 1970's, it was assigned to the boundary of the category of intermediate water quality, Class II, in 1990. The five point difference in the eutrophication index between the two sampling periods is likely insignificant and associated with interyear variability in parameters comprising the index. Aquatic macrophytes have been considered problematic since at least 1968 except in some nearshore areas where spot treatment with chemicals has periodically been recommended. Ciscos, a common cold water fish in 1954, were considered extirpated by 1974. The major period of eutrophication in Shriner Lake appears to have been during the period from the late 1930's through the 1940's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters decreased during the 1950's and have changed little since that time.

Macrophytes area considered problematic only in round Lake, but the DNR has never considered the extent of macrophytes to be detrimental to the lake's fishery. Any plant control at Round Lake must be approached cautiously. The best way to insure that current algal problems are not increased following control of macrophyte problems is to avoid overly zealous complete control of macrophytes in the lake.

The most serious fishery problem in the Tri-Lakes chain is the loss of ciscos, a cold water species requiring cold well oxygenated waters for its survival. Although annual accumulations of phosphorus, and presumably eutrophication, changed little during the past 20 years when cisco populations were declining toward extirpation, predator species such as brown trout were stocked regularly. It is suggested that brown trout not be stocked to the lakes until its impact on ciscos can be evaluated fully.

INTRODUCTION

DESCRIPTION OF TRI-LAKES WATERSHED

The Tri-Lakes Watershed is located primarily in northern Whitley County with a small portion of the watershed extending into Noble County, Indiana. The Tri-Lakes are tributary to Thorn Creek and the Eel River in the Mississippi River Watershed.

The area of the watershed above the outlet control structure below Round Lake is approximately 2174 acres. The total area of the four principal Lakes: Shriner, Cedar, Little Cedar, and Round is 403 acres. The remaining watershed including Catfish Lake and several significant wetlands and ponds contains approximately 1771 acres.

Cedar and Little Cedar Lakes were once regarded as one lake. The construction of a causeway across the lake for a road and development has effectively isolated the two lakes, and each lake now displays significantly different water quality.

Cedar Lake, Little Cedar Lake and Round Lake, are the same elevation (902 ft. M.S.L.) and are connected by navigable channels. Water flow direction is from Cedar through Little Cedar to Round Lake outletting into Thorn Creek.

Shriner Lake (elev. 907 ft. M.S.L.) historically outlet through a natural drainage way (through the Shoreline Restaurant Property) directly into Thorn Creek. The outlet was diverted to Round Lake via the Indiana Department of Natural Resources Fish Hatchery in approximately 1912, however, a Report of the State Geologist publication indicates the dredged channel in 1900.

PURPOSE

Members of the Property Owners Association have become increasingly concerned with the perceived deterioration of water quality in the lakes. Principal areas of concern include poor runoff water quality in inflowing streams, shoaling at stream inlets, and increased weed concentrations and algal blooms. The growing environmental awareness of local residents, and the desire to reverse the causes of cultural eutrophication were primary factors for the authorization of the study.

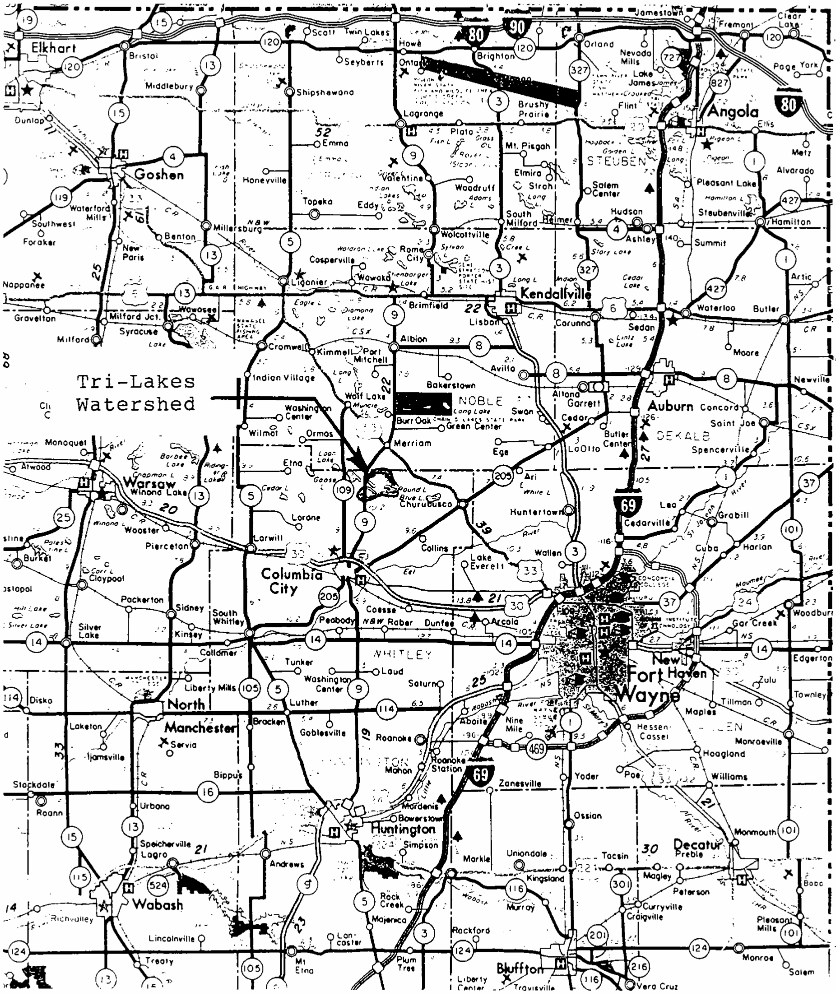

Figure 1. Tri-Lakes Watershed location map

The principal objectives of the study were fourfold:

1. Map the Tri-Lakes Watershed and its principal drainage courses and subwatersheds.

2. Map land use and Highly Erodible Soils in the watershed and identify areas of concern which may pose a threat to the health of the lake system.

3. Assess the historical and current conditions of the lakes and establish baseline data for the continued assessment of lake water quality.

4. Provide information and develop recommendations to assist the Tri-Lakes Property Owners Association in the management of their watershed and lakes system.

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LAKES SURVEY

LIMNOLOGICAL AND PALEOLIMNOLOGICAL METHODS

PHYSICAL/CHEMICAL PARAMETERS

All water quality parameters for individual lakes (Shriner, Big Cedar, Little Cedar, Round) were collected on 16 August 1990 from a single central sampling station near the point of maximum water depth. Dissolved oxygen and temperature profiles were determined with a YSI oxygen meter, and light transmission was estimated with a Secchi disc and a Licor photometer. Water samples for chemical and chlorophyll analyses were taken from composite samples of the water column where a Kemmerer bottle was used to collect water at each meter of the water column. All analyses were performed in certified laboratories according to EPA techniques (EPA-600/14-79-020, Methods for Chemical Analysis of Water and Wastes, Revised March 1983). Data for physical and chemical parameters for each lake during the 1990 survey are presented in the appropriate chapter of this report devoted to the lake in question.

PHYTOPLANKTON

Phytoplankton were collected with a #20 Wisconsin plankton net equipped to open and close at discrete depth intervals. Two samples were collected at each lake. The first was a vertical haul through the water column from a depth of five feet to the surface, and the second was a five foot vertical haul that spanned the thermocline. Both collections were specified for calculation of the IDEM Eutrophication Index. Alcohol preserved samples were settled in Utermohl chambers and counted using an inverted microscope.

MACROPHYTES

A raytheon recording fathometer was used to estimate the biovolume of aquatic macrophytes in each lake. A total of 10-19 transects spanning the width of each lake was used as the data base. The plant survey was conducted in August 1990 and thus represents summer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of macrophyte infestation throughout the lake system. In addition to the raytheon survey, each lake was visually surveyed to note the extent of plant taxa.

FISH

The Raytheon fathometer data recorded from the 10-19 cross lake transects were also used to provide a qualitative assessment of the fish community of each lake. Echos of fish in the water column appeared on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for the lakes.

BATHYMETRIC MAP AND LAKE INFILLING

The State of Indiana constructed bathymetric maps of each lake during the period 1922-1925. Depth contours were constructed at five foot intervals for each lake. The current study constructed updated bathymetric maps for all lakes for 1990 based on fathometer recordings obtained from 10-19 lake transects. Following convention established by the 1922-1925 maps, five foot contours were constructed for the 1990 maps. The area of each depth contour for both 1920's and 1990 maps was determined by a digitizing planimeter, and the extent of basin infilling between the two periods was estimated via comparison of the areas of respective contour intervals.

SEDIMENT CORE COLLECTION

A modified Livingstone piston coring device (Livingstone 1955) equipped with a clear 4.1 cm ID cellulose buterate tube was used to collect sediment cores from the deep water sections of all lakes. Sites were selected that were felt to minimize sediment focusing from shallow water areas of the lakes. The coring technique permitted examination of each core to insure that the sediment-water interface was not disturbed during the coring operation. All cores were extruded within two hours of collection and sectioned at 1 cm intervals with each sample being placed in a plastic bag for storage. All samples were then kept at 4^{o} C until analyzed.

SEDIMENT PARAMETERS AND TOTAL PHOSPHORUS

One cm^3 sediment samples from select core levels were placed in small procelain crucibles of known dry weight, and wet weight of the sediment was measured using a Mettler analytical balance. Water loss (% water) was calculated after reweighing the samples following dessication for 24 hours at 100^{o} C. Inorganic and organic fractions were determined by weight loss following ignition at 550^{o} C for one hour. Samples were allowed to cool to room temperature in a dessicator before weighing.

Determination of total phosphorus for select core levels utilized the ignition method of Anderson (1976). Inorganic residue from the loss on ignition analysis just described was washed into a 200 mL beaker using 25 mL of 1N HCl and boiled for 15 minutes on a hot plate. Each sample was then diluted to 100 mL, and orthophosphate was measured by the ascorbic acid method (APHA 1985) using a Bausch and Lomb spectrophotometer equipped with a 1 cm light path. For the latter analyses, reagent blanks were run after every five sediment samples.

LEAD-210 DATING OF SEDIMENT CORES

Each of the sediment cores were dated utilizing state of the art ^{210}Pb methodology. ^{210}Pb concentrations were measured by direct gamma assay using a coaxial N-type, intrinsic-germanium detector (Princeton Gamma Tech). This type of detector counts over a large range of gamma energies and can be used for simultaneous measurement of supported and unsupported ^{210}Pb or other gamma-emitting radioisotopes of environmental interest (Appleby et al. 1986, Nagy 1988. An outer shield (0.95 cm steel), main shield (10.1 cm lead), and an inner lining (0.05 cm cadmium + 0.15 cm copper) were used to reduce background radiation at the germanium detector.

Samples for isotope analysis were dried at 100^{o} C for 24 hours, pulverized by mortar and pestle, weighed, and placed in small plastic petri dishes (#1006, Falcon, CA). Core sections were combined (up to 4 cm) to obtain an adequate sample weight (generally > 3 grams). Petri dishes were sealed with plastic cement and left for 14 days to equilibrate radon (^{222}Rn) with radium (^{226}Ra). Counting times varied from 14 to 45 hours depending on sample weight; small samples needed to be counted longer to minimize uncertainty. Blanks were counted for every two samples to determine background radiation. Standards were run with the same frequency to track efficiency (counts/gamma) and calculate a ^{226}Ra conversion factor (pCi/cps).

Sample spectra were analyzed for activity in the 46.5 keV for ^{210}Pb, and activities at 295 keV (^{214}Po), 352 keV (^{214}Pb) and 609 keV (^{214}Bi) representing uranium series peaks were used to compute supported levels of ^{210}Pb. Calculation of ^{210}Pb dates followed the constant rate of supply model (Appleby and Oldfield 1978), which is able to quantify changing sedimentation rates.

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CEDAR LAKE

and

LITTLE CEDAR LAKE

INTRODUCTION

Cedar Lake (Big + Little), Whitley County, is a 131 acre lake with a maximum and mean depth of 75 feet and 30 feet, respectively. Legal lake level is 902 feet and is controlled by a concrete dam on the outlet from Round Lake. The lake has no permanent inlets, and the outlet is via an unnamed channel to Round Lake. The present study was initiated because of lake residents' concerns regarding observation of siltation associated with delivery of erosion products from the watershed especially during early spring rains.

The current chapter is designed to define the current water quality of Cedar Lake and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on water quality for Cedar Lake. The second section summarizes the water quality analyses conducted as part of the present study and compares values to earlier studies. The third and final section details our sediment studies at Cedar Lake where we were interested in determining the extent of basin infilling in the historical past as well as changes in phosphorus loading to the lake. Management implications of our analysis of past and current water quality will be discussed later in this report. Note that a majority of past studies have not designated whether they were conducted in Little or Big Cedar Lakes. Unless otherwise noted, we have assumed that these studies were conducted in Big Cedar. Where possible, we have tried to separate our analyses into Big and Little Cedar components.

Historical Water Quality

Historical Database

A total of 12 separate studies were conducted on Cedar Lake between 1925 and 1990 for which data were available (Table C1). The Indiana Department of Conservation constructed a bathymetric map for Cedar Lake in 1925. Collection of water quality data on the lake began in 1930 with the investigation of Will Scott of Indiana University, and D.G. Frey assessed the cisco populations in 1955. Detailed water quality surveys of the lake did not begin until 1967 when the Indiana Department of Natural Resources began surveying the fish community of the lake. The Indiana DNR conducted seven studies between 1967 and 1988. The Indiana Department of Environmental Management (IDEM)

Table C1. Chronology of Investigations at Big-Little Cedar Lake, IN

1925	Indiana Department of Conservation. Construction of bathymetric map for Cedar Lake.
1930	Indiana University. Survey of physical/chemical parameters, phytoplankton and zooplankton. Published by Scott (1931).
1955	David G. Frey. Assessment of status of ciscos in Cedar Lake.
1967	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1974	Indiana Department of Natural Resources. Dissolved oxygen profile and gill netting in "cisco layer" to assess status of cisco population. Published by Gulish (1974).
1975	Indiana Department of Environmental Management. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index.
1978	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1981	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1981	Indiana Department of Natural Resources. Creel census of fish harvested from Cedar Lake. Published by Braun (1982).
1985	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters to determine status of ciscos in Cedar Lake.
1988	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters to determine status of ciscos in Cedar Lake.
1990	Indiana Department of Environmental Management. Survey conducted by Indiana University of physical, chemical, and biological parameters for construction of IDEM eutrophication index.

Table C2. Historical chemistry.

Cedar and Little Cedar Lake Historical Data		July 1967	Aug.1975	July 1978	July 1981	Aug.1985	Aug.1988	July 1990	Aug.1990
Secchi	feet	16.5	21	12.1	15	19.3	15	19.7	20.8
Mean DO	mg/L	4.15		3.22	3.82	4.97	5.46	5.6	3.6
Alkalinity	mg/L	108		181	154	145	162	149	146
pH		8		8.4	8.4	8.25	8.5	7.7	
Conductivity	umhos/cm							320	388
Ca	mg/L	88							
Fe	mg/L	0.1							
K	mg/L	3							
Mg	mg/L	72							
Mn	mg/L	0.05							
Na	mg/L	12							
Cl	mg/L	16							
SO4	mg/L	22							
Total Phosphorus	mg/L	1.1	0.04					0.09	0.11
Ortho Phosphorus	mg/L							0.08	
Nitrate-N	mg/L	0.1						0.42	0.6
Ammonia-Nitrogen	mg/L							0.13	0.19
Organic Nitrogen	mg/L							0.93	1.9
Total Kjeldahl N	mg/L								2.09
Chlorophyll	mg/m3								17

visited the lake once in the early 1970's to collect water chemistry and biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. Finally, Indiana University recently (1990) collected data on the lake as part of a water quality assessment grant from IDEM to assess changes in lake trophic state since the 1970's.

Physical/Chemical Parameters

A total of five physical and chemical parameters have been measured at Cedar Lake at a frequent enough intervals to be useful in delineating historical trends (Table C2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As Secchi values have historically been recorded during summer at Cedar Lake, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that Secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months (Table C2). All Secchi values collected for Cedar Lake were for July and August, and the most recent values for both months were within the range reported for these months since 1967. On the basis of Secchi data alone, it does not appear that the trophic state of Cedar Lake has changed markedly since at least 1967.

As with Secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal production. A good measure of the degree of eutrophication is provided by the extent of water column anoxia (absence of oxygen) in mid summer (Table C3). Since at least 1967, pronounced water column anoxia has been evident by at least July in Cedar Lake and extends throughout the summer stratified period. Although the historical database is not extensive, it appears that water column anoxia has not become more severe in recent years.

Alkalinity is a measure of the carbonate buffering capacity of lakes and can be a useful parameter for assessing changes in watershed delivery of erosion products through human activities. Oscillations in alkalinity values for Cedar Lake since 1967 do not yield any apparent trend that can be related to changes in watershed management practices (Table C2). It does not appear that the drought of 1988 had any major effect on lake alkalinity levels.

Although the database is rather limited, total phosphorus concentrations in Cedar Lake fail to display any significant historical trend (Table C2). The remaining

Table C3. Historical Records of Water Column Anoxia in Big Cedar Lake, IN

Observation	Initial Depth of <1 mg/L Dissolved Oxygen
July:	
1967	45 feet
1978	45 feet
1981	30 feet
1988	61 feet
August:	
1985	30 feet
1988	35 feet
1990	57 feet

physical and chemical parameters measured at Cedar Lake were sampled so infrequently as to be of little value in delineating past trends in water quality.

Microbiology

Neither the Whitley County Health Department nor the Indiana State Board of Health had any historical microbiological data from Cedar Lake.

Phytoplankton

Phytoplankton samples have been collected four times since 1930. Will Scott (1931) collected zooplankton and phytoplankton samples from discrete intervals of the water column during August 1930. The Indiana Department of Environmental Management sampled phytoplankton during August 1975, but detailed data were missing from the departmental files. The final survey of phytoplankton was by Indiana University in July 1990, but details were not provided.

Algal abundance in the surface waters of Cedar Lake during August 1930 was estimated at 130/mL (Table C4). *Anabaena* was the dominant taxon with *Fragilaria* and *Clathrocystis* as the principal subdominants. The presence of several taxa of blue-green algae was suggestive of a moderate degree of production. Algal abundance in surface waters of Big Cedar Lake for August 1990 was estimated at 3,582/mL and the assemblage was dominated by diatom and blue-green taxa. Although the database is limited, the phytoplankton assemblage of Cedar Lake appears to have increased in abundance since 1930, with many of the same taxa still dominating the algal assemblage.

Macrophytes

The macrophyte (aquatic plant) community was examined two times (1967 and 1978) as part of Indiana Department of Natural Resources fish surveys (Table C5). Plant taxonomic composition was nearly identical for the two surveys. Submergent macrophytes were the most taxonomically diverse plant community with pondweeds displaying the greatest number of species. Although it was noted that macrophytes grew to depths of 15 feet, neither of the two plant surveys felt that macrophytes were a serious management problem.

Fish

The Indiana Department of Natural Resources surveyed the fish community of Cedar Lake five times between 1967 and

Table C4. Phytoplankton and zooplankton abundances and concentrations of dissolved gases in Cedar Lake in 1930. Table from Scott (1931). Key: (D) depth, (T) temperature, (O) oxygen, (Co_2) carbon dioxide, (Cb) carbonates.

LAKE: BIG CEDAR (Whitley)
Date: 8/12/30

Plankton

Species	0-5	5-10	10-15	15-20
Ceratium	4.2	8.5		12.8
Dinobryum		4.2		
Aneura				
Noltholca		12.8	4.2	
Polyarthra				
Asplancna	8.5	4.2		
Hexarthra	4.2		8.5	12.8
Daphnia	2.4	10.4	15	28.8
Diaptomus	5.6	16	.8	
Cyclops	3.2	14.4	14.4	11.2
Nauplii	17	46.9	76	81
Corethra		21	4.2	
Melosira		4.2		
Fragillaria	25	25	64	110
Asterionella		12.8	59	42
Anabena	68	136	29	29
Clathrocyctis	21	298	89	153
Oscillatoria		8.5	4	
Lyngbya	12.7	119	21	12

Dissolved Gases

D	T	O	%	CO_2	Cb
S	26.1	5.38		—1.4	28.8
2	25	5.35		—1.4	29.2
4	24.4	5.69		—1.0	28.2
6	17.7	6.71		—1.4	29.2
8	13.3	7.10		—1.4	31.8
10	10.3	5.97		—1.0	31.8
12	8.8	4.57		.4	32.0
14	7.2	2.90		2.0	31.6
21.5	6.1	40		2.0	31.6

Table C5. Historical data on macrophyte composition.

Cedar and Little Cedar Lake
Macrophytes

Species	Common Name	1967	1978
SUBMERGENTS:			
Ceratophyllum demersum	coontail	X	X
Chara spp.	chara	X	X
Elodea canadensis	elodea	X	X
Myriophyllum heterophyllum	water milfoil	X	
Najas spp.	slender naiad		X
Potomogeton amplifolius	largeleaf pondweed	X	
Potomogeton illinoensis	Illinois pondweed	X	
Potomogeton natans	floating lf pondweed	X	X
Potomogeton pectinatus	sago pondweed	X	
Potomogeton richardsonii	Richardson's Pondwee	X	X
Potomogeton zosteriformis	flatstem pondweed	X	X
Ranunculus spp.	waterbuttercup	X	
Vallisneria americana	wild celery	X	X
EMERGENTS:			
Decodon verticillatus	swamp loosestrife	X	
Juncus effusus	soft rush	X	
Peltandra virginica	arrow arum	X	X
Polygonum spp.	smartweed		X
Pontederia cordata	pickeral weed	X	
Sagittaria latifolia	arrowhead	X	X
Scirpus americanus	bulrush	X	X
Typha latifolia	common cattail	X	
FLOATING LEAVED:			
Nuphar advena	spatterdock	X	X
Nuphar microphyllum	spatterdock	X	
Nymphaea odorata	waterlily	X	X
FREEFLOATING:			
Lemna minor	duckweed	X	X

Table C6. Historical DNR Fish Sampling in Big-Little Cedar Lake, IN.

1967	Electrofishing:	3 hrs night
	Gillnets:	3 for 96 hrs = 288 hrs total effort
	Traps:	19 for 96 hrs = 1824 hr total effort
1978	Electrofishing:	1.3 hrs night, 1 hr day
	Gillnets:	3 for 96 hrs = 288 hrs total effort
	Traps:	3 for 96 hrs = 288 hrs total effort
1981	Electrofishing:	1.4 hrs night
	Gillnets:	3 for 72 hrs = 216 hrs total effort
	Traps:	3 for 72 hrs = 216 hrs total effort
1985	Gillnets:	3 for 48 hrs = 144 hrs total effort
1988	Gillnets:	3 for 48 hrs = 144 hrs total effort

1988. All DNR surveys were based on a combination of electrofishing, gill net, and trap collections, the details of which are presented in Table C6. In addition to the detailed surveys, spot checks for ciscos were also conducted periodically.

A listing of the individual species caught and the contribution of each to total fish abundance and weight caught during the five DNR surveys are provided in Tables C7 and C8, respectively. Bluegill was the most abundant fish caught in the 1967 and 1978 surveys (26 and 45%) followed by warmouth (13% and 12%). By 1981, bluegill (15%) was tied with warmouth (15%) as the most abundant fish of the survey, with largemouth bass and yellow perch (14%) being the second most abundant. Brown bullhead (29%) were the most abundant fish in the 1985 survey followed by warmouth (19%) and black bullhead (15%). On a weight basis, largemouth bass dominated both the 1978 and 1981 surveys (16% and 15%), and brown bullhead (26%) dominated the 1985 survey.

Fish stocking into Cedar Lake has been practiced by the Indiana DNR since at least the early 1960's and was likely conducted by residents prior to that. Fish known to have been stocked into the lake include brown trout, rainbow trout, and tiger muskellunge.

Ciscos were considered common in Cedar Lake in 1954, rare by 1975, and extirpated by 1988. An angler caught the state record cisco from Cedar Lake, and another angler claimed he caught a cisco from the lake in 1984. No DNR surveys have reported catching ciscos in the lake since 1978. This fish species requires cold well oxygenated water and is therefore sensitive to deoxygenation of the lower water column associated with increasing eutrophication. The historical cisco data suggest that water quality in Cedar Lake may be have been declining recently. Although the limited historical water chemistry database does not indicate this trend, inherent sensitivity of the cold water fishery to reduced dissolved oxygen conditions in the lower water column may be an early warning indicator of slowly degrading water quality.

Current Water Quality

The sampling locations for current water quality data for Big and Little Cedar Lakes collected on 16 August 1990 are shown in Figure C1, and data for physical and chemical parameters are presented in Table C9.

Table C7. Historical data on fish abundance expressed as a percent of total fish abundance from DNR surveys.

Cedar Lake % Total Fish Abundance	1967	1978	1981	1985
Black Bullhead			2.2	15.8
Black Crappie	0.3	1.7	0.2	
Bluegill	26.7	45.4	15.3	5.3
Bowfin	0.3	0.5	0.7	
Brown Bullhead	0.4	1.1	3.5	29.8
Brown Trout		0.8	5.2	1.8
Carp	0.2			1.8
Golden Shiner	0.2	0.1	0.2	1.8
Grass Pickeral	1.8	0.4	3.2	
Green Sunfish	12.2			
Lake Chubsucker	9.8	6	6.2	1.8
Largemouth Bass	12.3	7.9	14.1	
Northern Pike				1.8
Pumpkinseed	4.5	5	7.9	
Rainbow Trout				12.3
Redear	13.1	9.3	3.7	
Rock Bass	1.5	1.8	2.7	
Shortnose Gar	0.1			
Spotted Gar	1.1	2	1.2	3.5
Spotted Sunfish		0.3	0.7	
Tiger Muskellunge			1.7	
Warmouth	13.9	12.1	15.6	19.3
Yellow Bullhead	0.4	1.6	1.2	5.3
Yellow Perch	1.2	4.1	14.1	

Table C8. Historical data on fish weight expressed as a percent of total fish weight from DNR surveys.

Cedar Lake Fish Weight	1978	1981	1985
Black Bullhead		3.1	12.2
Black Crappie	2.2	0.8	
Bluegill	31	7.2	1.1
Bowfin	0.5	8.5	
Brown Bullhead	1.1	10.2	26.5
Brown Trout	0.8	15.7	1.6
Carp			18.4
Golden Shiner	0.1	0.1	0.4
Grass Pickeral	0.4	1.4	
Lake Chubsucker	5.1	4.1	0.5
Largemouth Bass	16.6	15.7	
Northern Pike			20.9
Pumpkinseed	2.7	3.4	
Rainbow Trout			12.4
Redear	5.4	2.8	
Rock Bass	1	1.2	
Spotted Gar	5.8	4.3	1.1
Spotted Sunfish	0.1	0.2	
Tiger Muskellunge		2.4	
Warmouth	6.6	5.2	2.4
Yellow Bullhead	5.1	1.7	2.6
Yellow Perch	3	12.3	

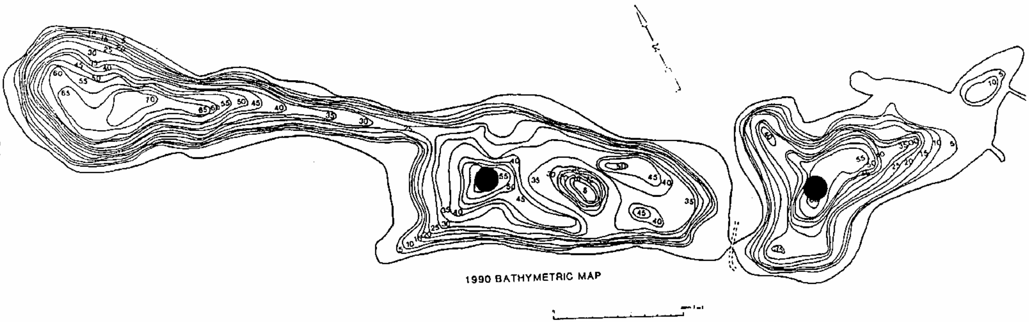


Figure C1. Sampling location for 1990 survey.

Table C9. Chemistry for 1990.

1990		Cedar 2 July*	Cedar 16 Aug.	Little Cedar 16 Aug
Secchi	feet	19.68	20.8	6.7
Mean DO	mg/L	5.6	3.6	1.5
Ammonia	mg/L	0.13	0.19	0.16
Total Kjeldahl N	mg/L		2.09	1.26
Organic-N	mg/L	0.93	1.9	1.1
Nitrate	mg/L	0.42	0.6	1.2
Total Phosphorus	mg/L	0.09	0.11	0.16
Ortho Phosphorus	mg/L	0.08	< 0.01	0.01
Conductivity	umho/cm	320.0	388.0	382.0
Alkalinity	mg/L	149.0	146.0	138.0
Chlorophyll	mg/m3		17.0	69.0
pH		7.7		
Temperature	C	9.9	14.9	11.9

* Data by Indiana University

Physical/Chemical Parameters

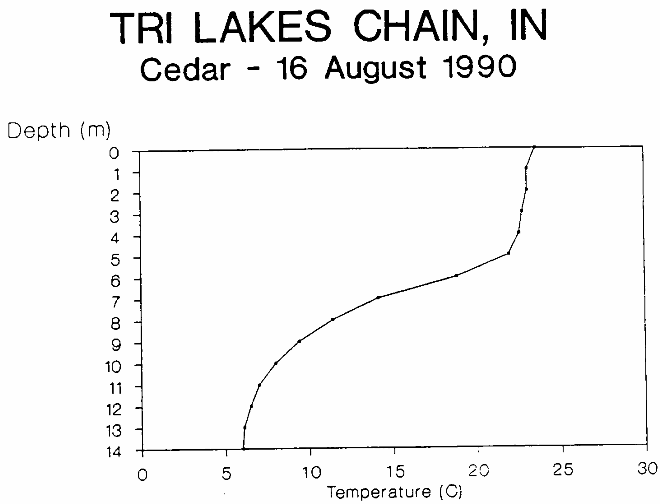
Temperature. The water columns of northern Indiana lakes greater than approximately five meters deep remain thermally stratified throughout most of the year. As a result of density-temperature relationships, complete mixing of the water column from top to bottom occurs only when water temperature reaches a uniform $4^{\circ}C$, the maximum density of water. This occurs twice a year in temperate lakes (spring and fall) associated with seasonal climatic changes. The length of the mixing period depends on the rapidity of climate change and can vary from a few days to less than a month. Lakes displaying two mixing periods per year are termed dimictic.

During the stratified period, the water column of Indiana lakes is divided into three zones based on temperature-density relationships. The uppermost well mixed zone is termed the epilimnion and extends from the surface to a depth roughly approximating the lower depth of wave action. The lowermost portion of the water column is the hypolimnion, a zone of density-isolated water that mixes with surface waters only during the short mixing periods. The portion of the water column that is transitional between the epilimnion and hypolimnion is termed the metalimnion. That one meter of the metalimnion displaying the greatest temperature change is called the thermocline.

The water column profiles clearly demonstrated that both Big and Little Cedar Lakes were thermally stratified during August 1990 (Figure C2). The thermocline was between six and seven meters in Big Cedar and between four and five meters in Little Cedar.

Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).

Pronounced water column deoxygenation was noted in both Big and Little Cedar during August 1990 (Figure C3). As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). Big Cedar and Little Cedar were essentially anoxic below depths of 11 meters and 3 meters, respectively. Finally, the



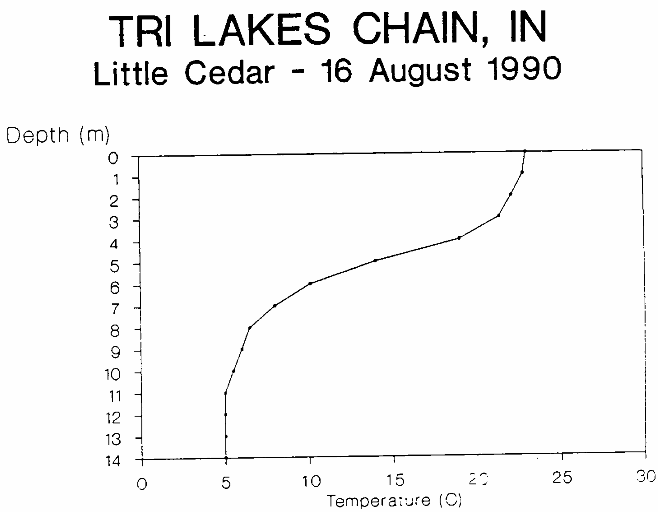
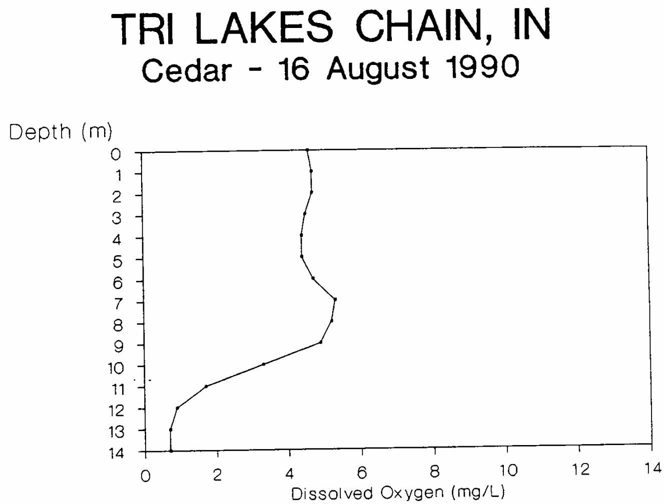


Figure C2. Temperature profiles for Big and Little Cedar Lakes in 1990.



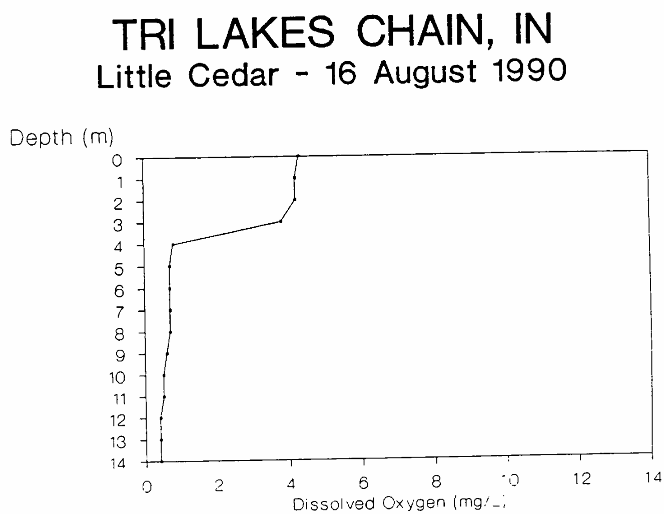


Figure C3. Dissolved oxygen profiles for Big and Little Cedar Lakes in 1990.

surface waters of both Big and Little Cedar as well as Shriner and Round Lakes appeared to be undersaturated with dissolved oxygen. Such conditions commonly exist during mid summer if conditions are sufficiently cloudy as to impair photosynthesis. If conditions are calm, the phytoplankton still remain near the lake surface and continue to respire, thus reducing near surface oxygen values.

While the overall trend in both lakes was for oxygen to decline with increasing depth, Big Cedar did display a zone of increased oxygen between 7 and 9 meters. Dissolved oxygen in this zone, however, did not exceed 5 mg/L. Such atypical oxygen curves as seen in Big Cedar are termed positive heterograde oxygen curves, and the deep water oxygen zone in natural lake is usually associated with a concentrated band of phytoplankton, whose photosynthesis produces a zone of elevated oxygen. While such deep water oxygenated zones are considered essential for the survival of ciscos in Indiana lakes, the concentration of oxygen in the deep water zone of Big Cedar is considered marginal for cisco survival.

Mean oxygen values for the water columns of both Big and Little Cedar in August 1990 were less than 5 mg/L suggesting eutrophic conditions (Table C9). Mean water column dissolved oxygen for our August 1990 survey, 3.6 mg/L for Big Cedar and 1.5 mg/L for Little Cedar, were lower than that reported for August surveys of 1985 (4.97 mg/L) and 1988 (5.46 mg/L) (Table C2). Historically, Cedar Lake has displayed severe deoxygenation of the water column as early as July (Table C3).

Secchi Disc Transparency. As stated earlier in this report, the depth that a Secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the Secchi depth during summer, the more productive (eutrophic) a lake is presumed to be. The 1990 Secchi value for Big Cedar (20.8 feet) was within the range reported for August at least since 1965. No historical data were available for comparison with the 6.7 feet reported for August 1990 in Little Cedar. Water clarity in Big Cedar is considered good. Based on the survey of the 1970's, IDEM observed that only 13% of the state's lakes had Secchi values greater than 10 feet. On the other hand, water clarity in Little Cedar is considered about average for an Indiana lake as evidenced by the findings of IDEM that approximately 50% of Indiana lakes display Secchi values of 5-10 feet during summer.

Nitrogen Forms. The 1990 ammonia values for Cedar Lake (0.19 mg/L Big Cedar, 0.16 mg/L Little Cedar) were similar to the only historical value for the lake (July 1990, 0.13 mg/L) (Table C2). Nitrite-nitrate nitrogen concentrations were greater during August 1990 (0.6 mg/L) in Big Cedar than for any date reported since 1967. No historical data were available for comparison with the 1.2 mg/L reported for Little Cedar for August 1990. Although no historical data could be found, Kjeldahl nitrogen values for August 1990 were 2.09 mg/L and 1.26 mg/L in Big and Little Cedar, respectively. Ammonia values for both Big and Little Cedar are considered low for Indiana lakes, while nitrite-nitrate values for both lakes are characteristic of mesotrophic to slightly eutrophic lakes.

<u>Phosphorus Forms</u>. Total phosphorus concentrations in August 1990 (0.11 mg/L Big, 0.16 mg/L Little) were within the range reported for Big Cedar for the period 1975-1990 but were lower than the 1.1 mg/L reported in 1967. Ortho phosphorus concentrations were below detection in Big Cedar during August 1990 and 0.01 mg/L in Little Cedar. Values for the only historical date found, July 1990, were 0.08 mg/L. During the 1970's survey, IDEM found that 24% of the state's lakes had total phosphorus values of 0.10-0.50 mg/L.

<u>Nitrogen:Phosphorus Ratios</u>. The ratio of total nitrogen to total phosphorus can be useful in delineating which of these two essential nutrients is limiting primary production in lakes. Numerous authors (Baker et al. 1981, Kratzer and Brezonik 1981, Canfield 1983) have proposed that N:P ratos less than 10 suggest nitrogen limitation, while those greater than 10 suggest phosphorus. The N:P ratios in Big Cedar and Little Cedar in August 1990 were 24.1 and 15.3, respectively. The ratio from the July 1990 survey of Cedar Lake by Indiana University has been calculated at 16.4. These values suggest that the lake is phosphorus limited at least during part of the summer growing season.

<u>Alkalinity and Conductivity</u>. The alkalinity values reported for August 1990 (146 mg/L Big Cedar, 138 mg/L Little Cedar) were within the range reported for this parameter (108-181 mg/L) since 1967. Although detailed historical data are lacking, the 388 umhos/cm and 382 umhos/cm reported during August 1990 in Big and Little Cedar, respectively, were similar to that reported for Cedar Lake during July 1990 (320 umhos/cm).

<u>Chlorophyll</u>. Chlorophyll is a good estimator of algal biomass in a lake. Chlorophyll concentrations during August 1990 were 17 mg/m^3 and 69 mg/m^3 for Big and Little Cedar, respectively. There are no historical data for comparison with the 1990 survey. Chlorophyll values for August 1990 were characteristic of eutrophic lakes.

<u>IDEM Trophic State Index</u>

Mr Harold BonHomme of the Indiana Department of Environmental Management (IDEM) devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined.

The 1975 eutrophication index for Cedar Lake was calculated by the Indiana Department of Environmental Management as 8, thus assigning the lake to the category of best water quality, Class One. Parameters for the 1990 index calculation were identical to those used for the 1975 index. Based on our August samplings, we have calculated the 1990 IDEM eutrophication index for Big Cedar Lake as 13 (Table C10) and for Little Cedar Lake as 35 (Table C11). Although not specified, it appears that the 1975 index was calculated for Big Cedar. While our 1990 value still placed Big Cedar in the category of best water quality, Class One, the 1990 value for Little Cedar placed the lake in the category of intermediate water quality, Class Two.

While there is general agreement between the 1975 (8) and our August 1990 (13) index calculations, these are in marked contrast with the 43 calculated for July 1990 by W. Jones of Indiana University. All physical/chemical parameters were roughly comparable between the two dates and it appears that the major difference was the dominance by blue-green algae during July. This is in marked contrast with the dominance of the assemblage by diatoms during August. <u>Lyngbya</u> was the only important blue-green taxon. Because of the weight placed on blue-green dominance in the eutrophication index, the presence of a blue-green algal bloom in July 1990 caused an extreme elevation of the eutrophication index.

The phytoplankton assemblage of Big Cedar during August 1990 was dominated numerically by <u>Fragilaria</u> with <u>Lyngbya</u> and <u>Tabellaria</u> as the principal subdominants (Table C12). Although <u>Tabellaria</u> was not present, the other two taxa were components of the plankton in August 1930 (Table C4) when the assemblage was dominated by <u>Anabaena</u> and secondarily by <u>Fragilaria</u>. The overall group composition of the plankton appears to have changed little since 1930 with blue-greens and diatom still playing a dominant role. The August 1990 phytoplankton assemblage of Little Cedar was dominated by the blue-green genus <u>Gloethece</u> with <u>Tabellaria</u> and <u>Lyngbya</u> as the principal subdominants (Table C12). Unfortunately, no historical data were available for this lake basin.

On the basis of IDEM eutrophication indices alone, it appears that Big Cedar is about as productive in 1990 as in 1975. Both the 1975 and 1990 values placed the lake in Class

I (best water quality). It must be remembered that the IDEM index is based on parameters collected for the water column in open water sections of the lake, and like all indices, does not include the extent and productivity of aquatic macrophytes. Expanding macrophyte abundance is often associated with reduced nutrient and algal abundance in open water areas as the vegetated littoral zone successfully competes with open water phytoplankton for nutrients (Canfield et al. 1983). We have seen no evidence, however, to suggest that macrophytes in Cedar Lake are extensive enough to influence calculation of the IDEM eutrophication index.

Microbiology

A water sample for fecal coliform and fecal strep analyses was collected on 16 August at the water quality station in the center of Big and Little Cedar Lakes. Samples were analyzed within eight hours of collection. The analyses followed the state approved membrane filter procedure and counts have been expressed as most probable numbers (mpn), a standard way of estimating bacterial numbers. The concentrations of fecal coliform bacteria were 16 mpn/100 mL and 640 mpn/100 mL in Big and Little Cedar, respectively, while fecal strep were undetected in either lake basin. Bacteria counts for fecal coliforms at Little Cedar Lake exceeded the state standard of 400 mpn/100 mL.

Macrophytes

A raytheon recording fathometer was used to estimate the biovolume of aquatic macrophytes in Cedar Lake. A total of 18 transects in Big Cedar and 11 transects in Little Cedar spanning the width of each lake were used as the data base. The plant survey was conducted in August 1990 and thus represents summer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of macrophyte infestation throughout the lake system.

The aerial distribution of plant biovolume in Little and Big Cedar Lakes is presented in Figure C4, and the percentage of lake area represented by individual biovolume increments is presented in Figure C5. For convenience, biovolume has been expressed in increments of 20% of water column infestation. Macrophytes generally were restricted to water depths less than 20 feet, thus limiting plant growth in the lake to near shore areas. Given the morphometry of the basin, a large area of the lake bottom (69% Big Cedar, 51% Little Cedar) was considered void of vegetation.

Table C10. IDEM Eutrophication Index for Big Cedar Lake in 1990.

	Parameter	Value	Eutrophy Points
I.	Total Phosphorus	0.11 ppm	3
II.	Soluble Phosphorus	<0.01 ppm	0
III.	Organic Nitrogen	1.90 ppm	3
IV.	Nitrate	0.60 ppm	2
V.	Ammonia	0.19 ppm	0
VI.	Dissolved Oxygen Saturation @ 5 feet	55%	0
VII.	Dissolved Oxygen (% of water column with >0.1 ppm DO)	95%	0
VIII.	Light Penetration (Secchi Disk)	20.8 feet	0
IX.	Light Transmission (1% at Three Feet)	72 %	0
X.	Total Plankton		
	Vertical Tow (5 ft to Surface)	3,582 cells/mL	4
	Blue-green Dominance	No	0
	Vertical Tow (Thermocline)	1,774 cells/mL	1
	Blue-green Dominance	No	0
	> 100,000 cells/mL	No	0
		1990 IDEM Index	13

Table C11. IDEM Eutrophication Index for Little Cedar Lake in 1990.

	Parameter	Value	Eutrophy Points
I.	Total Phosphorus	0.16 ppm	3
II.	Soluble Phosphorus	0.01 ppm	0
III.	Organic Nitrogen	1.10 ppm	3
IV.	Nitrate	1.20 ppm	3
V.	Ammonia	0.16 ppm	0
VI.	Dissolved Oxygen Saturation @ 5 feet	48%	0
VII.	Dissolved Oxygen (% of water column with >0.1 ppm DO)	100%	0
VIII.	Light Penetration (Secchi Disk)	6.7 feet	0
IX.	Light Transmission (1% at Three Feet)	25 %	4
X.	Total Plankton		
	Vertical Tow (5 ft to Surface)	37,890 cells/mL	10
	Blue-green Dominance	Yes	5
	Vertical Tow (Thermocline)	10,127 cells/mL	4
	Blue-green Dominance	Yes	5
	> 100,000 cells/mL	No	0
		1990 IDEM Index	35

Table C12. Phytoplankton Composition for Cedar Lake On 16 August 1990.

Big Cedar Lake

	Surface	Thermocline
Fragilaria	2,118	841
Lyngbya	725	285
Tabellaria	489	334
Dinobryon	250	314

Little Cedar Lake

	Surface	Thermocline
Gloethece	19,668	4,144
Tabellaria	7,718	2,008
Lyngbya	5,455	1,649
Fragilaria	3,386	1,280
Dinobryon	1,229	717
Anabaena	434	329

Surface = algal units/mL calculated from a vertical tow from a depth of five feet to the surface.

Thermocline = algal units/mL calculated from a five foot vertical tow that includes the thermocline.

Areas of greater than 80% water column infestation were aerially limited to areas immediately along the shore in Big Cedar, especially along the middle of the south shore. Only 6% of Big Cedar exhibited greater than 60% plant biovolume. In contrast, as a direct reflection of the extensive shallow areas at the east end of the basin, Little Cedar had 38% of its area characterized by greater than 60% plant biovolume.

Our work at other Indiana lakes (Eviston and Crisman 1988, Crisman et al. 1990, Eviston et al. 1990) has demonstrated that the public perceives a macrophyte problem only when plant biovolume exceeds 80% of the water column. Following this reasoning, Big Cedar does not have a macrophyte problem with the possible exception of the middle of the south shore, while Little Cedar has potential problems in the eastern 34% of the basin. The depth distribution of macrophytes is controlled both by basin morphometry and pronounced light limitation below 10 feet water depth. It is suggested further eutrophication of Big Cedar Lake could result in a pronounced exacerbation of macrophyte problems beyond current levels, but only in nearshore areas. In contrast, it appears that most suitable areas for macrophyte growth in Little Cedar have already been colonized to the maximum extent.

In addition to looking at the distribution of plant biomass in Cedar Lake, a qualitative survey was made to determine the distribution of the major plant species in the system (Figure C6). The plant assemblage of Big Cedar is rich in species of pondweeds (Potomogeton), with the principal secondary submergent in the basin being wild celery (Vallisneria). Patches of spatterdock (Nuphar) and waterlily (Nymphaea) were found along the entire shore. Pondweeds were poorly represented in Little Cedar and the submergent flora was dominated by filamentous algae and Vallisneria. As in Big Cedar, patches of spatterdock and waterlilies characterized the shoreline.

Fish

The Raytheon fathometer data recorded from the 18 and 11 cross lake transects for Big and Little Cedar, respectively, were also used to provide a qualitative assessment of the fish community of Cedar Lake. Echos of fish in the water column appeared on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for the lake basins.

Total fish abundance in open water areas of Big Cedar Lake was estimated at 5/1000 feet of fathometer transect, while the estimate for Little Cedar was 6/1000 feet. The greatest density of fish in Big Cedar (26% total abundance)

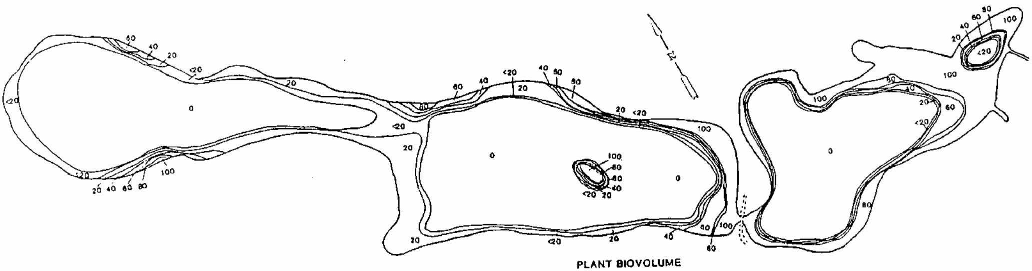
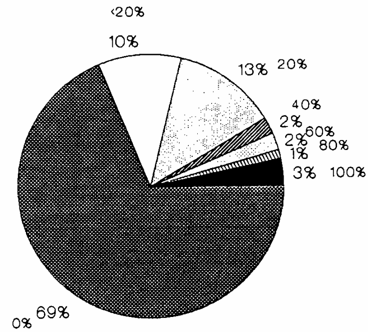


Figure C4. Plant biovolume map for 1990.

Cedar Lake, IN
Percent Plant Biovolume



Little Cedar, IN
Percent Plant Biovolume

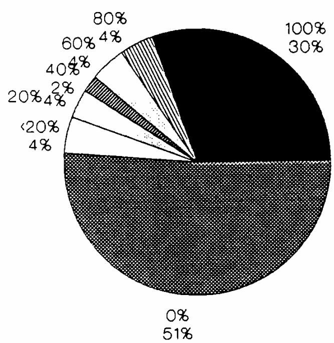


Figure C5. Plant biovolume partitioning for 1990.

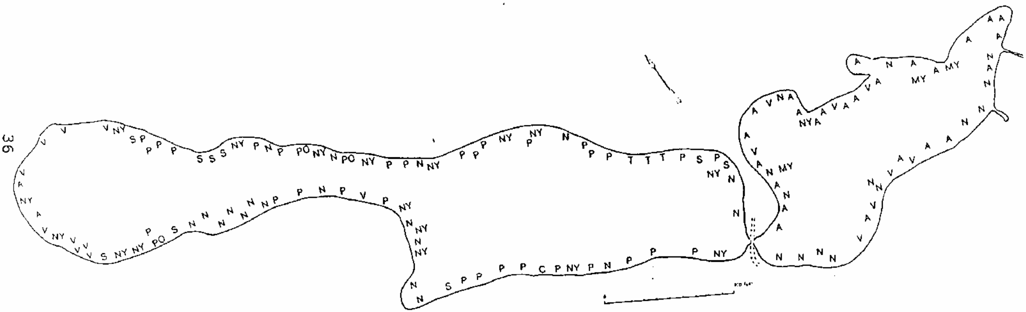


Figure C6. Plant taxa distribution for 1990. Taxa include filamentous algae (A), *Ceratophyllum* (C), *Myriophyllum* (MY), *Nuphar* (N), *Nymphaea* (NY), *Pontedaria* (PO), *Potomogeton* (P), *Typha* (T), and *Vallisneria* (V).

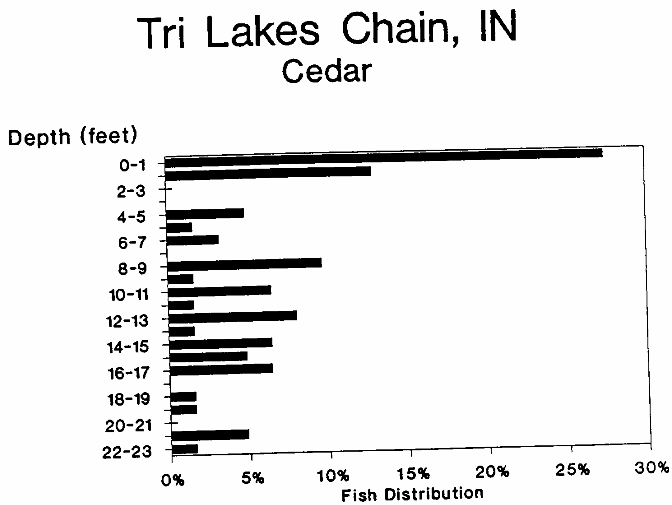
was at a depth of 0-1 feet (0.3 meter) with the second greatest density (12%) at 1-2 feet. (Figure C7). Similarly, the greatest density of fish in Little Cedar (26% total abundance) was at a depth of 1-2 feet (0.6 meter) with the second greatest density (19%) at 0-1 feet. Fish avoided depths deeper than 22-23 feet (7 meters) in Big Cedar and 12-13 feet (4 meters) in Little Cedar. Below four meters in Little Cedar, oxygen values were less than 0.4 mg/L, while in Big Cedar oxygen values did not drop to less than 0.7 mg/L until a depth of 12 meters. It must be noted, however, that oxygen is only one of many factors controlling fish distributions. Macrophytes such as found at lake depths less than 10 feet provide a prime habitat for both feeding and reproduction and are a major contributing factor to fishery production.

Bathymetric Map and Lake Infilling

The Indiana Department of Natural Resources published a bathymetric map of Cedar Lake based on a survey of 1925 (Figure C8). Depth contours were constructed at five foot intervals for the lake. The current study constructed an updated bathymetric map for 1990 based on fathometer recordings obtained from 18 lake transects from Big Cedar and 11 transects from Little Cedar (Figure C9). Following convention established by the 1925 map, five foot contours were constructed for the 1990 map.

A comparison of the depth configurations in Big Cedar for 1925 and 1990 is provided in Figure C10. The 30-35 foot contour in 1925 comprised approximately 18 acres, an area larger than displayed by an other single contour. The second largest contour was the 0-5 foot contour (15 acres). The deepest section of the lake (greater than 75 feet) was less than 0.5 acres. As in 1925, the 30-35 foot contour displayed the largest aerial extent in 1990 (19 acres), and the 0-5 foot contour (15 acres) was the second most important contour. The deep water zone (greater than 75 feet) in 1990 had all but disappeared.

A comparison of the depth configurations in Little Cedar for 1925 and 1990 is provided in Figure C11. The 0-5 foot contour in 1925 comprised approximately 13 acres, an area larger than displayed by an other single contour. The second largest contour was the 30-35 foot contour (4 acres). The deepest section of the lake (greater than 60 feet) was less than one acre. As in 1925, the 0-5 foot contour displayed the largest aerial extent in 1990 (17 acres), and the 30-35 foot contour (4 acres) was the second most important contour. The deep water zone (greater than 60 feet) in 1990 had all but disappeared.



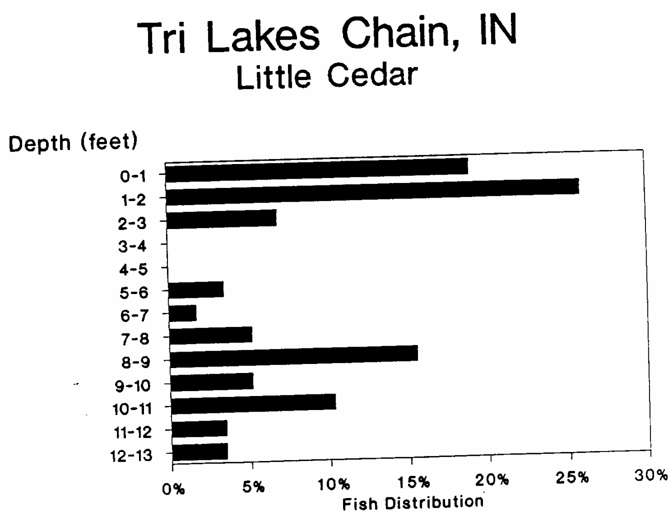


Figure C7. Fish distributions by depth for 1990.

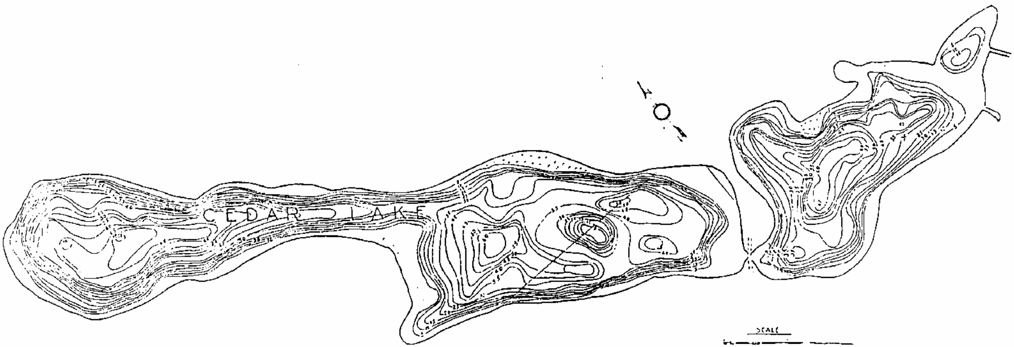


Figure C8. 1925 bathymetric map.

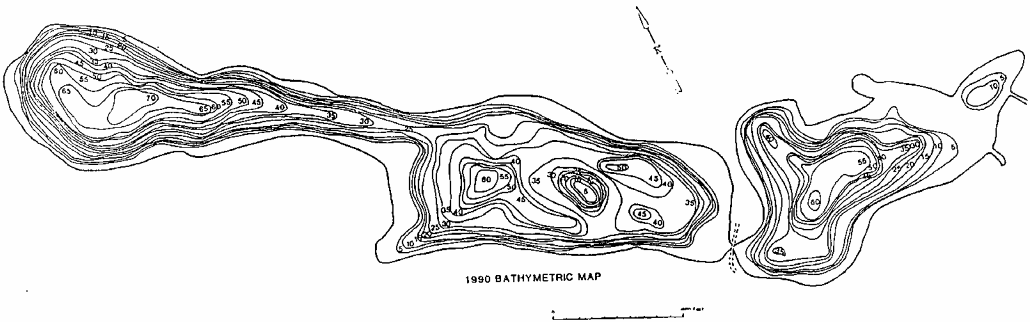
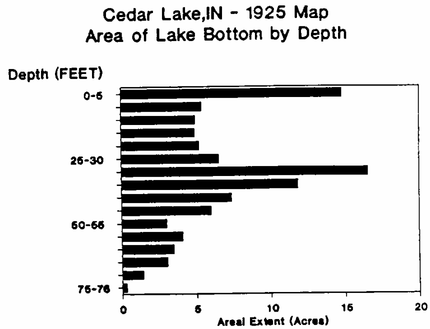
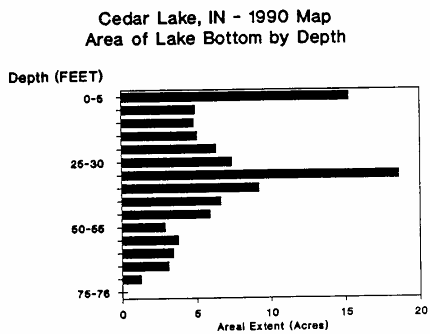


Figure C9. 1990 bathymetric map.





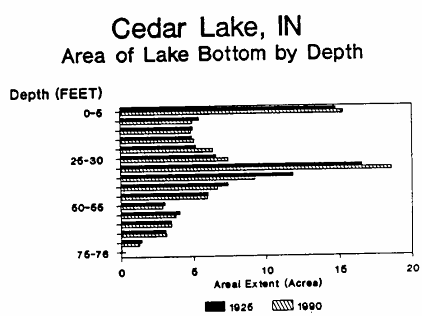
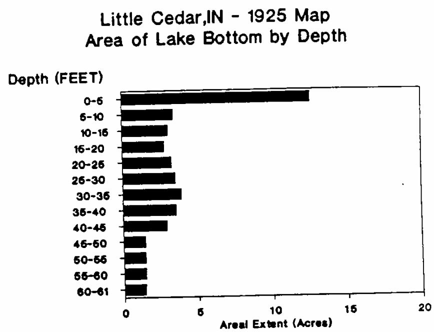
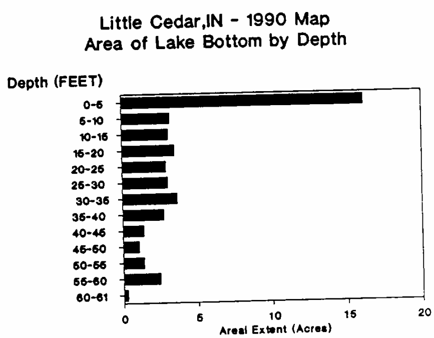


Figure C10. Aerial extent of individual depth contours in Big Cedar for 1925 and 1990 expressed in five





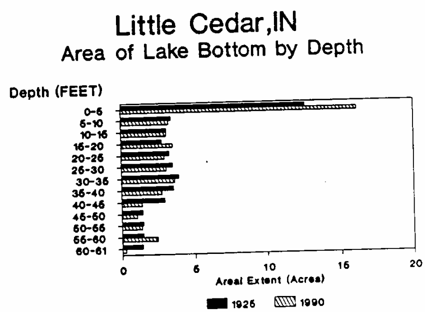


Figure C11. Aerial extent of individual depth contours in Little Cedar for 1925 and 1990 expressed in five

Table C13. Percent change in the extent of individual depth contours between 1925 and 1990.

Lake Depth	Cedar Change	Little Cedar Change	Combined Change
0-5	+ 3.4%	+ 27.8%	+ 14.6%
5-10	- 9.3%	- 5.9%	- 8.0%
10-15	- 4.0%	0.0%	- 2.5%
15-20	+ 4.1%	+ 25.0%	+ 11.7%
20-25	+ 21.6%	- 12.1%	+ 8.2%
25-30	+ 13.8%	- 11.4%	+ 5.0%
30-35	+ 12.1%	- 7.7%	+ 8.3%
35-40	- 22.7%	- 25.0%	- 23.2%
40-45	- 10.8%	- 51.7%	- 22.3%
45-50	- 1.7%	- 21.4%	- 5.4%
50-55	- 3.3%	- 6.7%	- 4.4%
55-60	- 3.0%	+ 66.7%	- 12.5%
60-65	0.0%	- 78.6%	- 22.4%
65-70	0.0%	----	0.0%
70-75	- 7.1%	----	- 7.1%
75-76	-100.0%	----	-100.0%

Sedimentation patterns for the past 65 years can be delineated through comparison of the aerial extent of individual contours for 1925 and 1990 (Table C13). The aerial extent of the 20-25 foot contour in Big Cedar Lake increased by 21% between 1925 and 1990. The depths in this basin showing the second greatest increase in aerial extent were 25-30 and 30-35 feet, which increased by 13% and 12%, respectively. In addition to the loss of areas greater than 75 feet, depth intervals showing the greatest loss in extent in Big Cedar were 35-40 (22%), 5-10 (9%) and 40-45 (10%).

The aerial extent of the 55-60 foot contour in Little Cedar Lake increased by 66% between 1925 and 1990. The depths in this basin showing the second greatest increase in aerial extent were 0-5 and 15-20 feet, which increased by 27% and 25%, respectively. Depth intervals showing the greatest loss in extent in Little Cedar were 60-65 (78%), 40-45 (51%) and 35-40 (25%).

Infilling of nearshore areas was not uniform throughout Cedar Lake between 1925 and 1990. The most pronounced sedimentation has taken place in the deep water areas at the western end of Big Cedar and especially in the northeastern and northwestern segments of Little Cedar. It is clear that basin sedimentation is strongly controlled by watershed erosion products. All three of these areas receive watershed runoff, the details of which will be discussed in the watershed section of this report. Two other contributors to lake infilling, motor boating and shoreline erosion, are possibly contributing factors for the observed pattern of sedimentation in Cedar Lake but were beyond the scope of the current study.

Sediment Studies

Sediment Core Profiles

A piston coring device equipped with a clear plexiglass tube was used to collect a 85 cm core from the deep water areas of Big Cedar and Little Cedar Lakes (Figure C12). Water content of the Big Cedar core remained at greater than 80% below a depth of 25 cm, but was at 63-84% from that depth to the surface (Figure C13). In contrast, the water content of the Little Cedar core displayed little stratigraphic varability and remained at greater than 80% along most of its length. The more compact nature of the upper 25 cm of the Big Cedar core is clearly related to the fact that the sediments became increasingly inorganic dominated above this depth (Figures C14 and C15). Organic content of the sediments shifted from 30-55% below 25 cm to

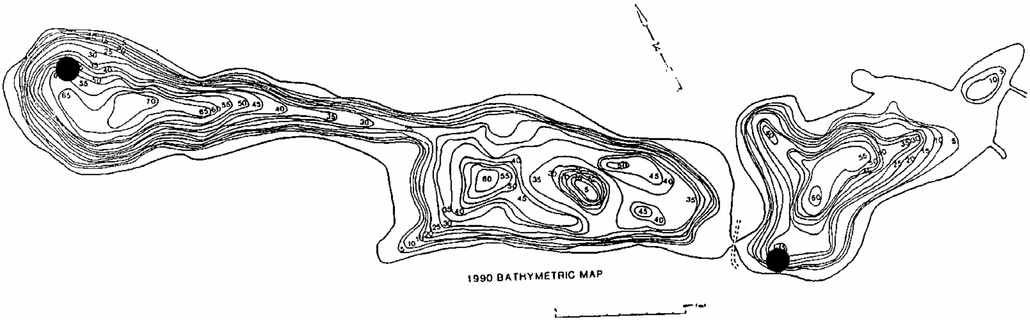
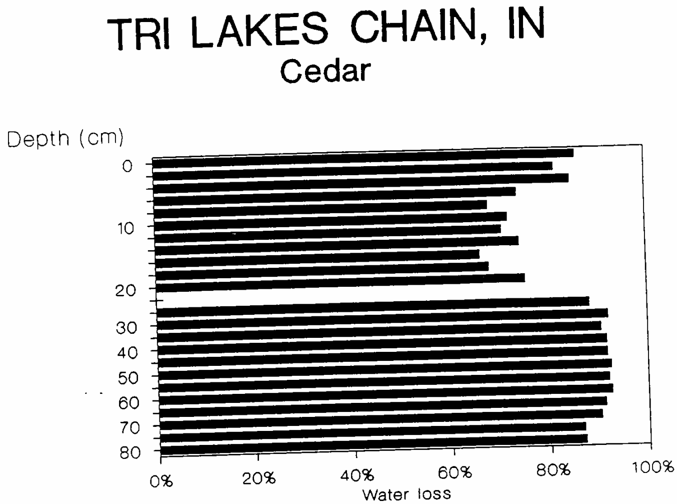


Figure C12. Location for 1990 sediment cores.



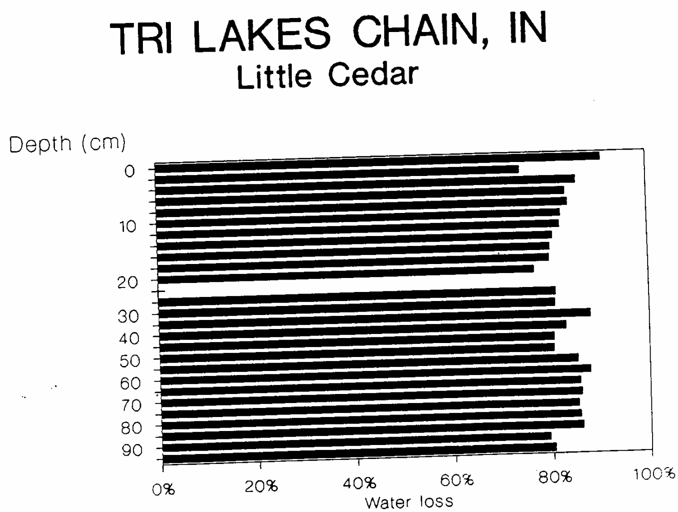
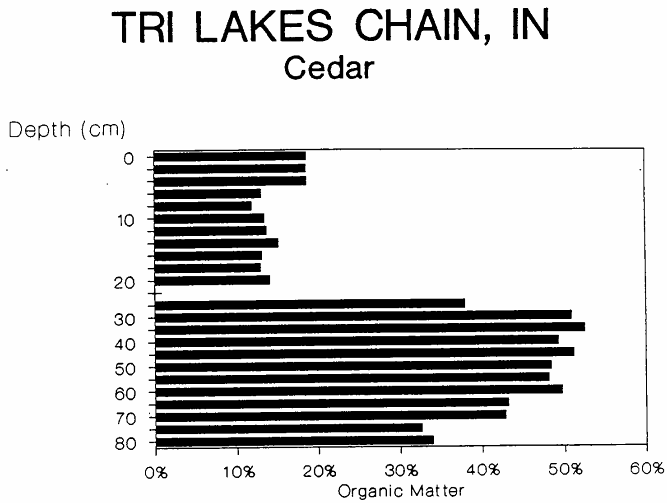


Figure C13. Profile of percent water in sediment core.



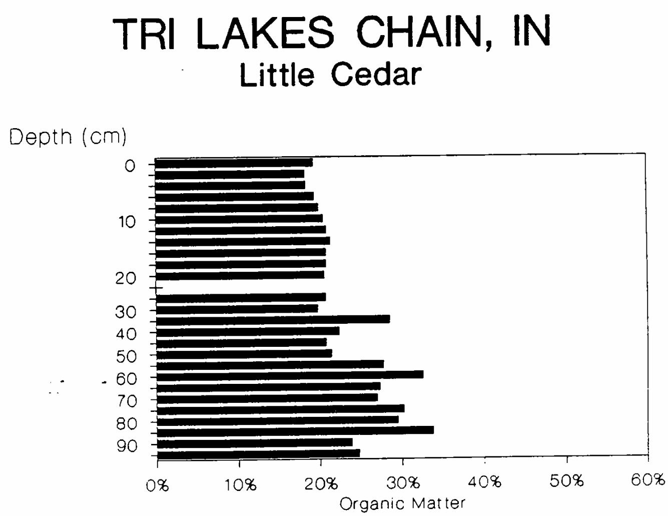
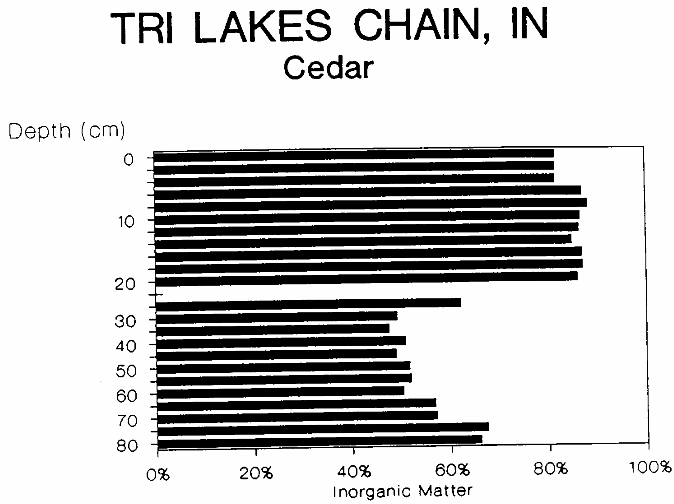


Figure C14. Profile of percent organic matter in sediment core.



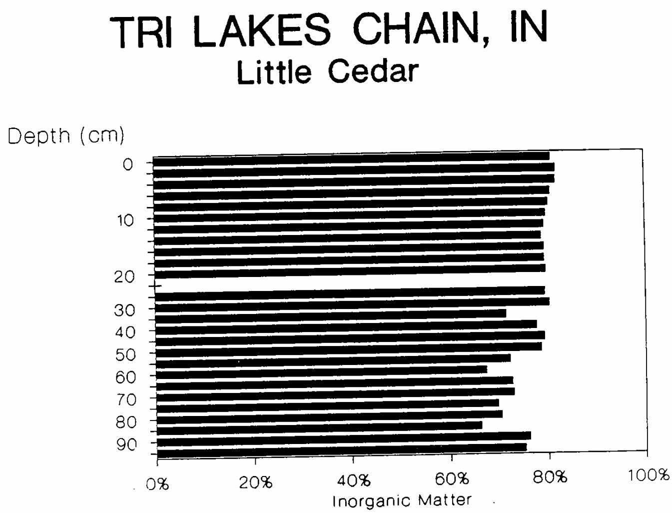


Figure C15. Profile of percent inorganic matter in sediment core.

less than 16% above this depth. The Little Cedar core also exhibited a reduction in the contribution of organic matter above 25 cm depth. The idea that the shift to a more inorganic dominated sediment is the result of increased delivery of watershed erosion products is supported by the previously discussed comparison of 1925 and 1990 bathymetric maps.

Total dry sediment accumulation rate increased progressively in Big Cedar from the mid 1800's into the early 1930's after which it remained high but fluctuated widely to the late 1970's. Values of the 1980's were reduced relative to the previous four decades and approximated levels characteristic of the basin in the mid 1920's (Figure C16). Sediment accumulation rates in Little Cedar increased from the mid 1800's through the early 1950's, after which they have plateaued but fluctuated somewhat during the mid 1960's and late 1970's.

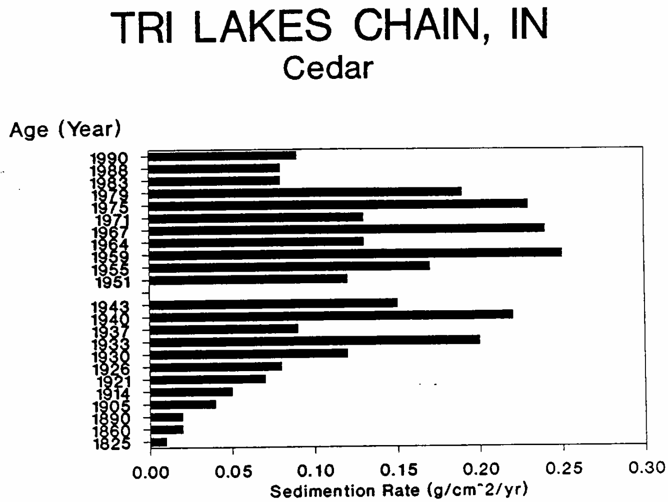
The accumulation of organic sediments in Big Cedar increased progressively from the mid 1800's to peak core values during the 1930's and 1940's (Figure C17). Accumulation rates fell sharply in the late 1940's and have remained relatively constant since then. Unlike Big Cedar, organic sedimentation rates increased progressively from the mid 1800's until the mid 1940's, after which they have remained relatively constant to the present.

Unlike organic matter which peaked in the 1930's and 1940's, inorganic matter sedimentation rates in Big Cedar peaked in the 1960's and 1970's (Figure C18). Inorganic sedimentation rates declined in the 1980's to levels approximating the 1930's. Inorganic sedimentation in Little Cedar peaked in the mid 1960's and the late 1970's, but unlike Big Cedar values did not decrease in the 1980's

Total phosphorus concentrations in the Big Cedar core were greatest between 30 and 80 cm and above 5 cm (Figure C19). Total phosphorus concentrations in the Little Cedar core were also highest in the upper 5 cm of the profile, but unlike Big Cedar, the remainder of the core profile displayed little pronounced stratigraphic variability. The profiles for phosphorus and organic matter in Big Cedar tracked well suggesting that most of the phosphorus entering the lake is biologically available (Figure C20). The relationship in Little Cedar, however, was not as pronounced.

Total phosphorus accumulation rates in Big Cedar increased progressively from the mid 1800's to the early 1930's after which they have fluctuated at high relatively constant levels (Figure C21). In contrast, total phosphorus accumulation rates in Little Cedar have tended to increase progressively from the mid 1800's to the present. Notable exceptions to this trend were the core peak reported in 1966 and a reduced value reported for 1972.

It appears that the major eutrophication period in the recent history of Big Cedar Lake was prior to the early 1930's when the delivery of inorganic sediment and total phosphorus increased markedly. Although interyear variability was noted after this period, the annual accumulation rate of phosphorus has not been altered markedly. In contrast to Big Cedar, however, total phosphorus accumulation rates in Little Cedar have increased steadily from initial land clearance to the present suggesting progressive eutrophication of the basin uninterrupted since the time of European colonization.



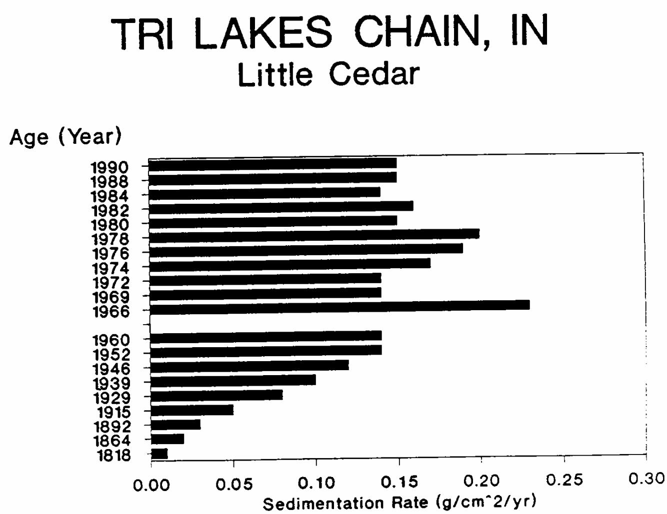
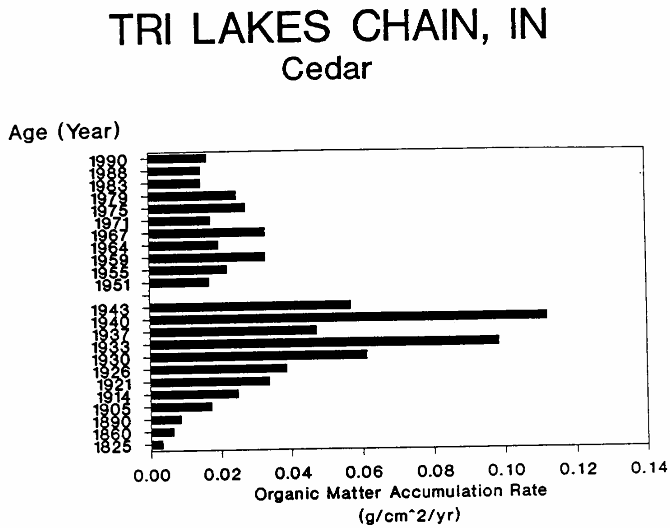


Figure C16. Sedimentation rate in Big and Little Cedar sediment cores.



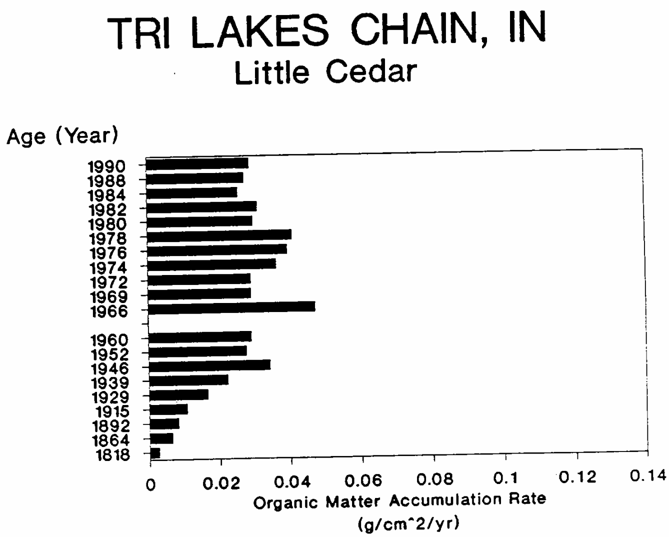
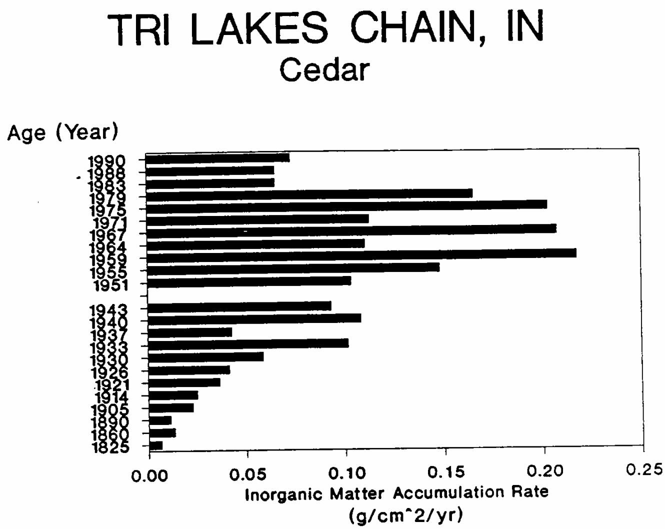


Figure C17. Organic matter accumulation rate in Big and Little Cedar sediment cores.



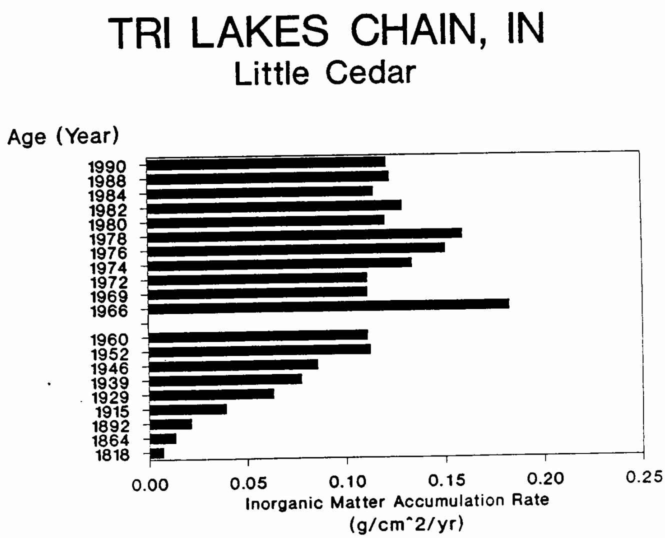
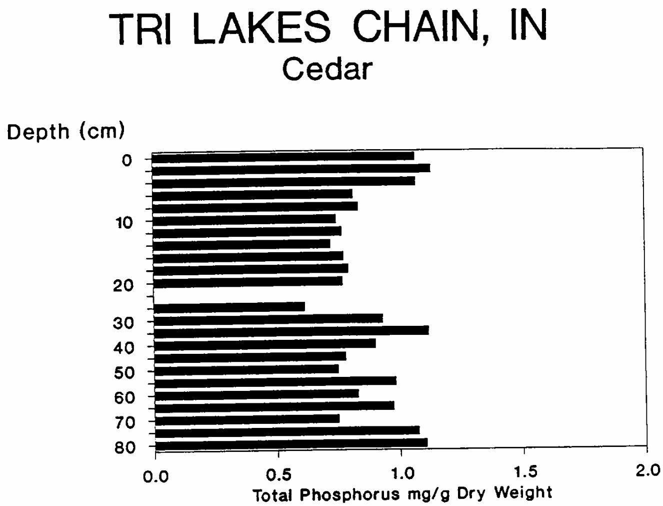


Figure C18. Inorganic matter accumulation rate in Big and Little Cedar sediment cores.



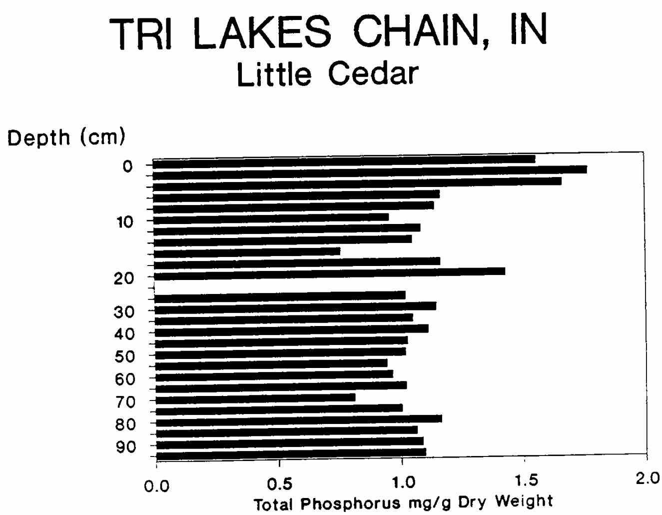
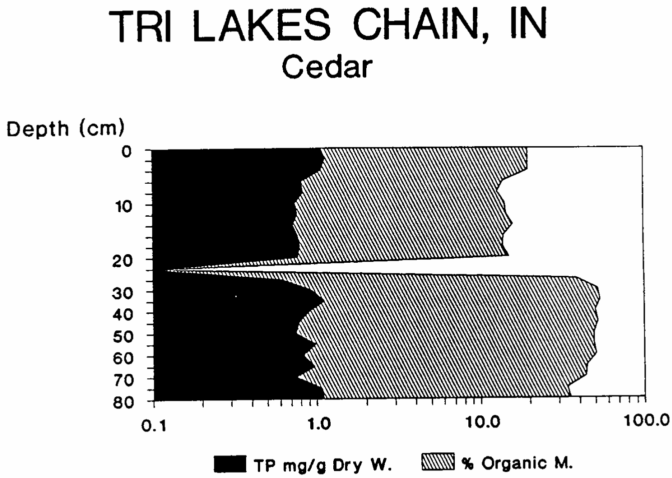


Figure C19. Total phosphorus concentrations in Big and Little Cedar sediment cores.



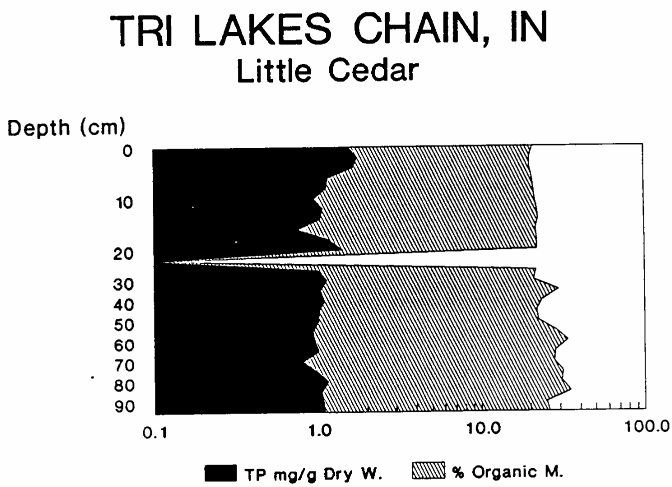
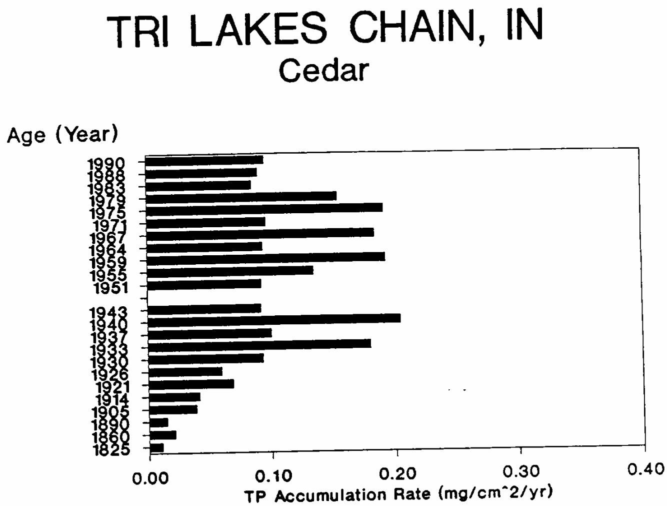


Figure C20. Relationship between total phosphorus concentrations and organic matter in Big and



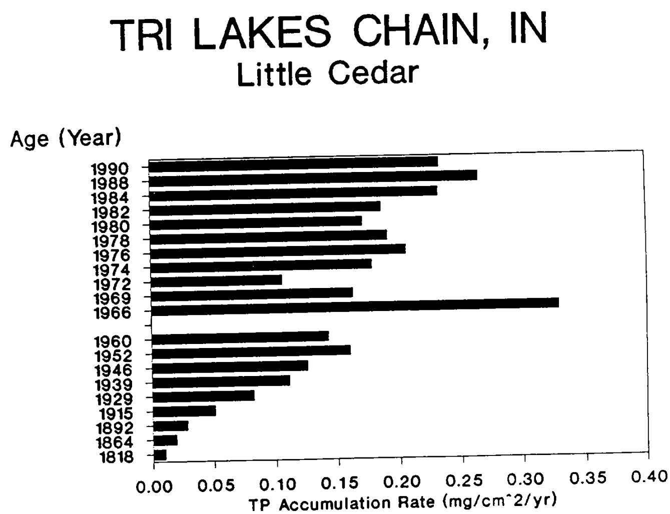


Figure C21. Accumulation rates of total phosphorus in Big and Little Cedar sediment cores.

ROUND LAKE

INTRODUCTION

Round Lake, Whitley County, is a 125 acre lake with a maximum and mean depth of 63 feet and 25 feet, respectively. Legal lake level is 902 feet and is controlled by a concrete dam in the outlet stream (Thorn Creek). The lake has two permanent inlets, one connecting with Cedar Lake along the northwest shore and the other connecting with Shriner Lake along the west shore. The present study was initiated because of lake residents' concerns regarding observation of siltation associated with delivery of erosion products from the watershed especially during early spring rains.

The current chapter is designed to define the current water quality of Round Lake and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on water quality for Round Lake. The second section summarizes the water quality analyses conducted as part of the present study and compares values to earlier studies. The third and final section details our sediment studies at Round Lake where we were interested in determining the extent of basin infilling in the historical past as well as changes in phosphorus loading to the lake. Management implications of our analysis of past and current water quality will be discussed later in this report.

Historical Water Quality

Historical Database

A total of 17 separate studies were conducted on Round Lake between 1925 and 1990 for which data were available (Table R1). The Indiana Department of Conservation constructed a bathymetric map for Round Lake in 1925. Collection of water quality data on the lake began in 1930 with the investigation of Will Scott of Indiana University, and D.G. Frey assessed the cisco populations in 1955. Detailed water quality surveys of the lake did not begin until 1968 when the Indiana Department of Natural Resources began surveying the fish community of the lake. The Indiana DNR conducted thirteen studies between 1968 and 1988. The Indiana Department of Environmental Management (IDEM) visited the lake once in the early 1970's to collect water chemistry and biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. Finally, Indiana University recently (1990) collected data on the lake as part of a

Table R1. Chronology of Investigations at Round Lake

1925	Indiana Department of Conservation. Construction of bathymetric map for Round Lake.
1930	Indiana University. Survey of physical/chemical parameters, phytoplankton and zooplankton. Published by Scott (1931).
1955	David G. Frey. Assessment of status of ciscos in Round Lake.
1968	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1974	Indiana Department of Natural Resources. Dissolved oxygen profile and gill netting in "cisco layer" to assess status of cisco population. Published by Gulish (1974).
1975	Indiana Department of Environmental Management. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index.
1978	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1979	Indiana Department of Natural Resources. Creel census of fish harvested in Round Lake. Published by Braun (1979).
1980	Indiana Department of Natural Resources. Evaluation of musky stockings in Round Lake. Published by Braun and Pearson (1980).
1981	Indiana Department of Natural Resouces. Creel census of fish harvested in Round Lake.
1982	Indiana Department of Natural Resources. Creel census of fish harvested in Round Lake. Published by Braun (1982).
1982	Indiana Department of Natural Resources. Evaluation of tiger muskellunge stocking. Published by Andrews and Laurion (1982).
1983	Indiana Department of Natural Resources. Creel census of fish harvested in Round Lake. Published by Braun (1983).

1983	<u>Indiana Department of Natural Resources</u>. Evaluation of tiger muskellunge stocking. Published by Andrews (1983).
1986	<u>Indiana Department of Natural Resources</u>. Evaluation of largemouth bass populations.
1988	<u>Indiana Department of Natural Resources</u>. Evaluation of fish harvest and largemouth bass and bluegill exploitation. Published by Walterhouse (1988).
1988	<u>Indiana Department of Natural Resources</u>. Assessment of largemouth bass populations.
1990	<u>Indiana Department of Environmental Management</u>. Survey conducted by Indiana University of physical, chemical, and biological parameters for construction of IDEM eutrophication index.

Table R2. Historical chemistry.

Round Lake Historical Data		July 1968	Aug. 1975	July 1978	July 1990	Aug. 1990
Secchi	feet	7.5	10	6.08	14.1	10.6
Mean DO	mg/L	2.96		2.96	2.5	1.8
Alkalinity	mg/L	102		127	131	117
pH		7.7		8.7	7.95	
Conductivity	umhos/cm				300	349
Total Phosphorus	mg/L		0.06		0.15	0.11
Ortho Phosphorus	mg/L				0.24	
Nitrate-N	mg/L				0.34	0.3
Ammonia-Nitrogen	mg/L				0.58	0.32
Total Kjeldahl N	mg/L					0.83
Organic N					0.856	0.51
Chlorophyll	mg/m3					36

60

water quality assessment grant from IDEM to assess changes in lake trophic state since the 1970's.

Physical/Chemical Parameters

A total of four physical and chemical parameters have been measured at Round Lake at a frequent enough intervals to be useful in delineating historical trends (Table R2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As Secchi values have historically been recorded during summer at Round Lake, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that Secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months (Table R2). All Secchi values collected for Round Lake were for July and August. No trends were seen in the data. On the basis of Secchi data alone, it does not appear that the trophic state of Round Lake has changed markedly since at least 1968.

As with Secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal production. A good measure of the degree of eutrophication is provided by the extent of water column anoxia (absence of oxygen) in mid summer (Table R3). Since at least 1968, pronounced water column anoxia has been evident by at least July in Round Lake and extends throughout the summer stratified period. On the basis of dissolved oxygen profiles, it does not appear that water column anoxia has become more severe in recent years.

Alkalinity is a measure of the carbonate buffering capacity of lakes and can be a useful parameter for assessing changes in watershed delivery of erosion products through human activities. Oscillations in alkalinity values for Round Lake since 1968 do not yield any apparent trend that can be related to changes in watershed management practices (Table R2).

Although the database is rather limited, total phosphorus concentrations in Round Lake fail to display any significant historical trend (Table R2). The remaining physical and chemical parameters measured at Round Lake were sampled so infrequently as to be of little value in delineating past trends in water quality.

Table R3. Historical Records of Water Column Anoxia in Round Lake, IN

Observation	Initial Depth of <1 mg/L Dissolved Oxygen
July:	
1968	20 feet
1978	15 feet
1990	42 feet
August:	
1990	45 feet

Microbiology

Neither the Whitley County Health Department nor the Indiana State Board of Health had any historical microbiological data from Round Lake.

Phytoplankton

Phytoplankton samples have been collected four times since 1930. Will Scott (1931) collected zooplankton and phytoplankton samples from discrete intervals of the water column during August 1930. The Indiana Department of Environmental Management sampled phytoplankton during August 1975, but detailed data were missing from the departmental files. The final survey of phytoplankton was by Indiana University in July 1990, but details were not provided.

Algal abundance in the surface waters of Round Lake during August 1930 was estimated at 22,343/mL (Table R4). Lyngbya was the dominant taxon with Fragilaria and Anabaena as the principal subdominants. The presence of several taxa of blue-green algae was suggestive of a moderate degree of production. Algal abundance in surface waters of Round Lake for August 1990 was estimated at 45,172/mL and the assemblage was dominated by blue-green taxa. Although the database is limited, the phytoplankton assemblage of Round Lake appears to have increased in abundance since 1930, with blue-green algae increasing in importance.

Macrophytes

The macrophyte (aquatic plant) community was examined three times from 1968 to 1982 as part of Indiana Department of Natural Resources fish surveys (Table R5). Plant taxonomic composition was similar for the three surveys. Submergent macrophytes were the most taxonomically diverse plant community with pondweeds displaying the greatest number of species.

The 1968 DNR survey noted that macrophytes, especially water milfoil, were a problem in Round Lake and proposed chemical control. The 1978 DNR survey proposed, however, limited control of macrophytes in the lake.

Fish

The Indiana Department of Natural Resources performed three detailed surveys of the fish community of Round Lake between 1968 and 1982. All DNR surveys were based on a combination of haul seines, electrofishing, gill net, and trap collections, the details of which are presented in

Table R4. Phytoplankton and zooplankton abundances and concentrations of dissolved gases in Round Lake in 1930. Table from Scott (1931). Key: (D) depth, (T) temperature, (O) oxygen, (CO_2) carbon dioxide, (Cb) carbonates.

LAKE: ROUND
Date: 8/12/30

Plankton						Dissolved Gases					
Species	0-5	5-10	10-15	15-20		D	T	O	%	CO_2	Cb
Ceratium	243	46	4.2			S	25	5.05	0	—1.0	22.4
Dinobryum	25.6					2	24.4	5.44		—1.0	21.6
Aneura	17	4.2				4	23.6	5.03		—1.4	21.6
						6	20.5	4.90		— .4	21.2
Polyarthra Asplancna Hexarthra	21 42	12.8				8	13.8	.24		3.0	28.8
Daphnia	7.2	1.6	1.6			10	10.5	.335		3.0	28.8
Bosmina		.8									
Diaptomus	14.4		.8								
Cyclops	20.8	3.2	.8			18	9.4	.0		3.0	31.2
Nauplii	68.2	25.6									
Melosira	38.4	38.4	64								
Fragillaria	2,517	409	132								
Asterionella		4.2									
Anabena	755	55	17								
Clathrocyctis	729	554	204								
Oscillatoria	98	25	85								
Lyngbya	17,937	742	593								

Table R5. Historical data on macrophyte composition.

Round Lake
Macrophytes

Species	Common Name	1968	1978	1982
SUBMERGENTS:				
Ceratophyllum demersum	coontail		X	X
Chara spp.	chara	X	X	X
Elodea canadensis	elodea	X	X	X
Myriophyllum exalbescens	water milfoil	X		X
Najas flexilis	bushy pondweed		X	X
Potomogeton amplifolius	largeleaf pondweed	X		X
Potomogeton crispus	curly leaf pondweed	X	X	X
Potomogeton foliosus	leafy pondweed			X
Potomogeton natans	floating leaf pondweed		X	X
Potomogeton Richardsonii	Richardson's pondweed	X		
Potomogeton strictifolius	fine leaf pondweed	X		
Potomogeton zosteriformis	flatstem pondweed	X	X	X
Vallisneria americana	wild celery	X	X	X
EMERGENTS:				
Juncus effusus	soft rush	X		
Peltandra virginica	arrow arum	X	X	X
Polygonum spp.	smartweed			X
Pontederia cordata	pickeral weed	X		
Sagittaria latifolia	arrowhead		X	X
Typha latifolia	common cattail	X		X
FLOATING LEAVED:				
Brasenia schreberi	watershield	X		
Nuphar advena	spatterdock	X	X	X
Nymphaea odorata	waterlily	X	X	X
FREE FLOATING:				
Lemna minor	duckweed		X	X

Table R6. Historical DNR Fish Sampling in Round Lake, IN.

1968	Gillnets:	3 for 72 hrs = 216 hrs total effort
	Traps:	14 for 72 hrs = 1008 hr total effort
	Seine Hauls:	100 foot each
1978	Electrofishing:	1 hr night, 1 hr day
	Gillnets:	3 for 96 hrs = 288 hrs total effort
	Traps:	3 for 96 hrs = 288 hrs total effort

Table R6. In addition to the detailed surveys, spot checks for ciscos and trout stocking success were also conducted periodically as well as creel censusing for tiger muskellunge and largemouth bass success.

A listing of the individual species caught and the contribution of each to total fish abundance and weight caught during the three DNR surveys are provided in Tables R7 and R8, respectively. Bluegill was the most abundant fish caught in the 1968, 1978 and 1982 surveys (33, 37, and 33%) followed by redear (16, 10, and 18%). On a weight basis, spotted gar (19%) and Redear (17%) were the most important fish of the surveys of 1978 and 1982, respectively.

Fish stocking into Round Lake has been practiced by the Indiana DNR especially for tiger muskellunge and was likely conducted by residents prior to that. The panfish fishery has always been considered to be good in Round Lake.

Ciscos were rare in Round Lake in 1954 but were considered extirpated by 1974. A 1988 survey also failed to report any ciscos. This fish species requires cold well oxygenated water and is therefore sensitive to deoxygenation of the lower water column associated with increasing eutrophication. The historical cisco data suggest that water quality in Round Lake may be have been declining recently. Although the limited historical water chemistry database does not indicate this trend, inherent sensitivity of the cold water fishery to reduced dissolved oxygen conditions in the lower water column may be an early warning indicator of slowly degrading water quality.

Current Water Quality

The sampling location for current water quality data for Round Lake collected on 16 August 1990 is shown in Figure R1, and data for physical and chemical parameters are presented in Table R9.

Physical/Chemical Parameters

Temperature. The water columns of northern Indiana lakes greater than approximately five meters deep remain thermally stratified throughout most of the year. As a result of density-temperature relationships, complete mixing of the water column from top to bottom occurs only when water temperature reaches a uniform 4^{o}C, the maximum density of water. This occurs twice a year in temperate lakes (spring and fall) associated with seasonal climatic changes. The length of the mixing period depends on the rapidity of climate change and can vary from a few days to less than a

Table R7. Historical data on fish abundance expressed as a percent of total fish abundance from DNR surveys.

Round Lake % Total Fish Abundance	1968	1978	1982
Black Bullhead		2.6	
Black Crappie	0.7	1.5	0.3
Bluegill	33	37.3	33
Bluntnose Minnow			1.9
Bowfin	0.3	0.9	0.3
Brown Bullhead	2.1	0.9	4.3
Brown Trout		0.4	0.2
Brook Silverside		0.4	0.2
Carp			0.1
Golden Shiner	0.1	0.1	
Grass Pickeral	1	0.9	2.1
Lake Chubsucker	10.9	7.9	6.5
Largemouth Bass	9.9	6.2	7.6
Madtom		0.1	
Northern Pike		0.1	
Pumpkinseed	2.3	2.6	3
Rainbow Trout	0.2		
Redear	16.8	10.2	18.2
Shortnose Gar	0.1		
Spotted Gar	0.4	3.2	0.6
Spotted Sunfish	6.2	0.6	0.4
Tiger Muskellunge			0.3
Warmouth	13.3	10.3	7.3
Yellow Bullhead	1.6	10.2	7.5
Yellow Perch	1	3.9	5.8

Table R8. Historical data on fish weight expressed as a percent of total fish weight from DNR surveys.

Round Lake Fish Weight	1978	1982
Black Bullhead	6.4	
Black Crappie	1.8	0.7
Bluegill	16.5	15.4
Bluntnose Minnow		0.1
Bowfin	7.9	2.2
Brown Bullhead	1.9	16.6
Brown Trout	0.8	0.7
Carp		0.4
Golden Shiner	0.1	
Grass Pickeral	0.6	1.3
Lake Chubsucker	7.5	4.7
Largemouth Bass	5.7	10.6
Northern Pike	3	
Pumpkinseed	1.2	1.5
Redear	3.9	17.7
Spotted Gar	19.8	2.6
Spotted Sunfish	0.2	0.3
Tiger Muskellunge		2.9
Warmouth	4.3	3.7
Yellow Bullhead	15.7	14
Yellow Perch	2.6	4.5

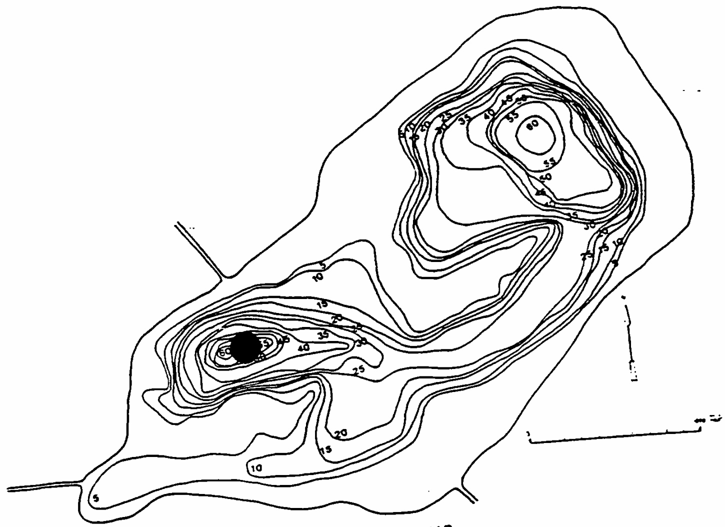


Figure R1. Sampling location for 1990 survey.

Table R9. Chemistry for 1990.

Round Lake	1990	2 July*	16 Aug.
Secchi	feet	14.1	10.6
Mean DO	mg/L	2.5	1.8
Ammonia	mg/L	0.58	0.32
Total Kjeldahl N	mg/L		0.83
Organic-N	mg/L	0.856	0.51
Nitrate	mg/L	0.34	0.3
Total Phosphorus	mg/L	0.15	0.11
Ortho Phosphorus	mg/L	0.24	< 0.01
Conductivity	umho/cm	300.0	349.0
Alkalinity	mg/L	131.0	117.0
Chlorophyll	mg/L		36.0
pH		7.95	
Temperature	C	11.6	14.6

* Data by Indiana University

month. Lakes displaying two mixing periods per year are termed dimictic.

During the stratified period, the water column of Indiana lakes is divided into three zones based on temperature-density relationships. The uppermost well mixed zone is termed the epilimnion and extends from the surface to a depth roughly approximating the lower depth of wave action. The lowermost portion of the water column is the hypolimnion, a zone of density-isolated water that mixes with surface waters only during the short mixing periods. The portion of the water column that is transitional between the epilimnion and hypolimnion is termed the metalimnion. That one meter of the metalimnion displaying the greatest temperature change is called the thermocline.

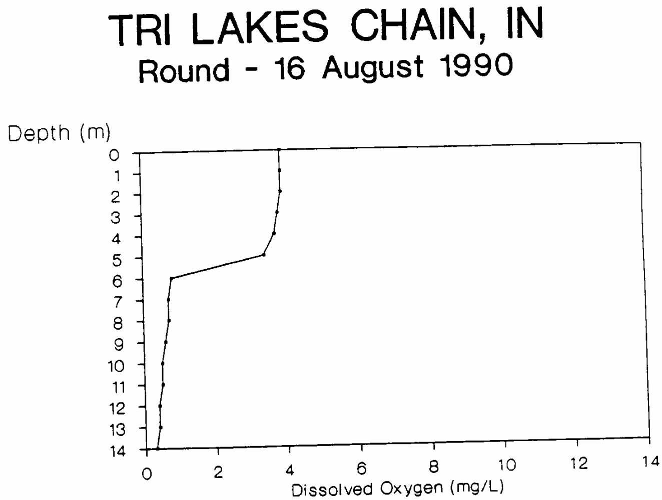
The water column profile clearly demonstrated that Round Lake was thermally stratified during August 1990 (Figure R2). The thermocline was between five and six meters.

Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).

Pronounced water column deoxygenation was noted during August 1990 (Figure R2). As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). The lake was essentially anoxic below a depth of 6 meters.

Mean oxygen values for the water column in August 1990 were less than 5 mg/L suggesting eutrophic conditions (Table R9). Mean water column dissolved oxygen for our 1990 survey (1.8 mg/L) was comparable to that of July 1990 (2.5 mg/L). Historically, Round Lake has displayed severe deoxygenation of the water column as early as July (Table R3).

Secchi Disc Transparency. As stated earlier in this report, the depth that a Secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the Secchi depth during summer, the more productive (eutrophic) a lake is presumed to be. The August



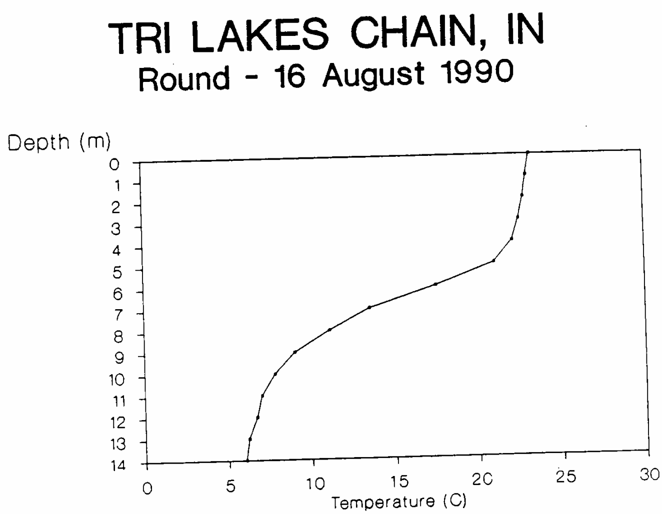


Figure R2. Temperature and dissolved oxygen profiles for Round Lake in 1990.

1990 Secchi value (10.6 feet) was equal to the value reported for August 1975. Based on the survey of the 1970's, IDEM observed that only 13% of the state's lakes had Secchi values greater than 10 feet. Thus, the water clarity for Round Lake is considered good for a typical Indiana lake.

<u>Nitrogen Forms</u>. The August 1990 ammonia value for Round Lake (0.32 mg/L) was lower than the only historical value for the lake (July 1990, 0.58 mg/L) (Table R2). Unlike ammonia, nitrite-nitrate nitrogen concentrations were equal during both August (0.3 mg/L) and July (0.34 mg/L) 1990. Although no historical data could be found, Kjeldahl nitrogen values for August 1990 were 0.83 mg/L. Ammonia values were considered of intermediate water quality for Indiana lakes, while nitrite-nitrate values were considered low for Indiana.

<u>Phosphorus Forms</u>. Total phosphorus concentrations were lower during August 1990 (0.11 mg/L) than July 1990 (0.15 mg/L). Both months were greater than the 0.06 mg/L reported for 1975. Ortho phosphorus concentrations were below detection in August 1990. Values for the only historical date found, July 1990, were 0.24 mg/L. While ortho phosphorus values were considered very low, total phosphorus values were considered indicative of mesotrophic lakes. During the 1970's survey, IDEM found that 24% of the state's lakes had total phosphorus values of 0.10-0.50 mg/L.

<u>Nitrogen:Phosphorus Ratios</u>. The ratio of total nitrogen to total phosphorus can be useful in delineating which of these two essential nutrients is limiting primary production in lakes. Numerous authors (Baker et al. 1981, Kratzer and Brezonik 1981, Canfield 1983) have proposed that N:P ratos less than 10 suggest nitrogen limitation, while those greater than 10 suggest phosphorus. The N:P ratio in Round Lake was 10.27 in August 1990 and 11.13 during the July 1990 survey of Indiana University. These values suggest that the lake is near to being nitrogen limited at least during part of the summer growing season.

<u>Alkalinity and Conductivity</u>. The alkalinity value reported for August 1990 (117 mg/L) was within the range reported for this parameter (102-131 mg/L) since 1968. Although detailed historical data are lacking, a similar parameter, conductivity, was higher during August 1990 (349 umhos/cm) than during July 1990 (300 umhos/cm).

<u>Chlorophyll</u>. Chlorophyll is a good estimator of algal biomass in a lake. Chlorophyll concentrations during August 1990 were 36 mg/m^3. There are no historical data for comparison with the 1990 survey. The August value for 1990 is characteristic of eutrophic lakes.

IDEM Trophic State Index

Mr Harold BonHomme of the Indiana Department of Environmental Management (IDEM) devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined.

The 1975 eutrophication index for Round Lake was calculated by the Indiana Department of Environmental Management as 30, thus assigning the lake to the category of intermediate water quality, Class Two. Parameters for the 1990 index calculation were identical to those used for the 1975 index. Based on our August samplings, we have calculated the 1990 IDEM eutrophication index for Round Lake as 22 (Table R10). Our calculation is comparable with the 20 calculated for July 1990 by W. Jones of Indiana University. Both 1990 index values placed the lake in the category of best water quality, Class One.

The phytoplankton assemblage during August 1990 was dominated numerically by *Lyngbya* with *Melosira* and *Fragilaria* as the principal subdominants (Table R11). All three taxa were components of the plankton in August 1930 (Table R4) when the assemblage was dominated by *Lyngbya* and secondarily by *Fragilaria*. The overall group composition of the plankton appears to have changed little since 1930.

On the basis of IDEM eutrophication indices alone, it appears that the lake is about as productive in 1990 as in 1975. While the 1975 value assigned the lake to Class Two, both the July and August 1990 values placed the lake in Class I (best water quality). It must be remembered that the IDEM index is based on parameters collected for the water column in open water sections of the lake, and like all indices, does not include the extent and productivity of aquatic macrophytes. Expanding macrophyte abundance is often associated with reduced nutrient and algal abundance in open water areas as the vegetated littoral zone successfully competes with open water phytoplankton for nutrients (Canfield et al. 1983). Although macrophytes are extensive in Round Lake, we have no data either to indicate whether they have expanded in recent years nor the extent to which they have influenced calculation of the IDEM eutrophication index.

Table R10. IDEM Eutrophication Index for Round Lake in 1990.

	Parameter	Value	Eutrophy Points
I.	Total Phosphorus	0.11 ppm	3
II.	Soluble Phosphorus	<0.01 ppm	0
III.	Organic Nitrogen	0.51 ppm	1
IV.	Nitrate	0.30 ppm	1
V.	Ammonia	0.32 ppm	1
VI.	Dissolved Oxygen Saturation @ 5 feet	46%	0
VII.	Dissolved Oxygen (% of water column with >0.1 ppm DO)	83%	0
VIII.	Light Penetration (Secchi Disk)	10.6 feet	0
IX.	Light Transmission (1% at Three Feet)	47 %	3
X.	Total Plankton		
	Vertical Tow (5 ft to Surface)	45,172 cells/mL	10
	Blue-green Dominance	Yes	5
	Vertical Tow (Thermocline)	7,293 cells/mL	3
	Blue-green Dominance	No	0
	> 100,000 cells/mL	No	0
		1990 IDEM Index	22

Table R11. Phytoplankton Composition for Round Lake On 16 August 1990.

	Surface	Thermocline
Lyngbya	27,878	1,785
Melosira	11,322	2,111
Fragilaria	4,213	1,229
Anabaena	1,288	1,189
Asterionella	380	680
Cosmarium	91	299

Surface = algal units/mL calculated from a vertical tow from a depth of five feet to the surface.

Thermocline = algal units/mL calculated from a five foot vertical tow that includes the thermocline.

Microbiology

A water sample for fecal coliform and fecal strep analyses was collected on 16 August at the water quality station in the center Round Lake. Samples were analyzed within eight hours of collection. The analyses followed the state approved membrane filter procedure and counts have been expressed as most probable numbers (mpn), a standard way of estimating bacterial numbers. The concentration of fecal coliform bacteria was 4 mpn/100 mL, while fecal strep were undetected. All bacteria counts at Round Lake during 1990 were well within state standards.

Macrophytes

A raytheon recording fathometer was used to estimate the biovolume of aquatic macrophytes in Round Lake. A total of 10 transects spanning the width of the lake were used as the data base. The plant survey was conducted in August 1990 and thus represents summer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of macrophyte infestation throughout the lake system.

The aerial distribution of plant biovolume in Round Lake is presented in Figure R3, and the percentage of lake area represented by individual biovolume increments is presented in Figure R4. For convenience, biovolume has been expressed in increments of 20% of water column infestation. Macrophytes generally were restricted to water depths less than 20 feet, thus limiting plant growth in the lake to near shore areas. Given the morphometry of the basin, only 43% of the lake bottom was considered void of vegetation.

The water column of approximately 33% of the lake area was considered 100% filled with macrophytes. These areas were essentially limited to depths less than five-seven feet deep. Given the steep slope of the basin, only an additional 24% of the lake area displayed any macrophyte growth.

Our work at other Indiana lakes (Eviston and Crisman 1988, Crisman et al. 1990, Eviston et al. 1990) has demonstrated that the public perceives a macrophyte problem only when plant biovolume exceeds 80% of the water column. Round Lake has approximately 39% of its lake area characterized by greater than 80% plant biovolume. Thus, the lake does have a macrophyte problem especially in near shore shallow areas. The depth distribution of macrophytes is controlled both by basin morphometry and pronounced light limitation below 10 feet water depth. It is suggested that macrophytes have completely colonized all habitats available to them and that further eutrophication of Round Lake is not

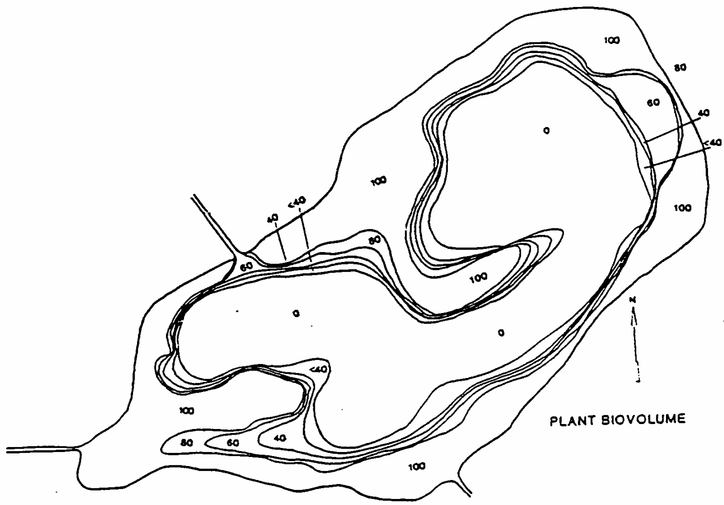


Figure R3. Plant biovolume map for 1990.

Round Lake, IN
Percent Plant Biovolume

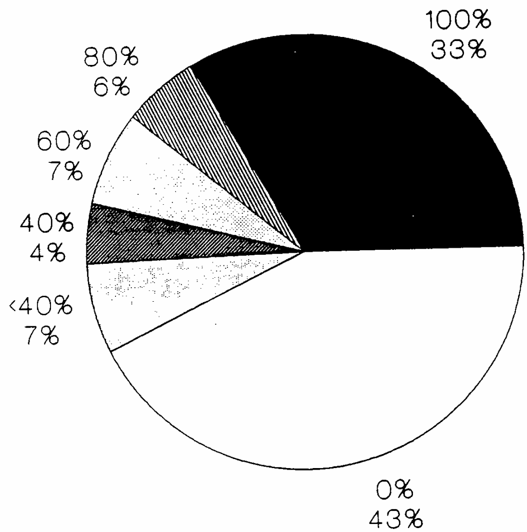


Figure R4. Plant biovolume partitioning for 1990.

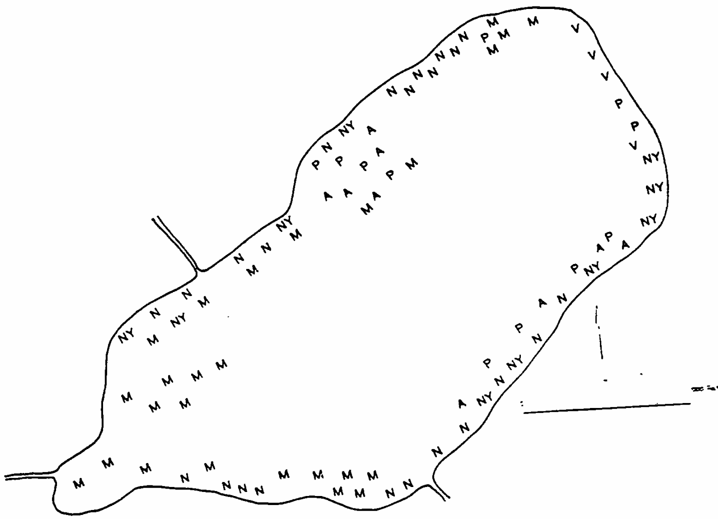


Figure R5. Plant taxa distribution for 1990. Taxa include filamentous algae (A), Myriophyllum (M), Nuphar (N), Nymphaea (NY), Potomogeton (P), and Vallisneria (V).

likely to result in a pronounced exacerbation of macrophyte problems beyond current levels.

In addition to looking at the distribution of plant biomass in Shriner Lake, a qualitative survey was made to determine the distribution of the major plant species in the system (Figure R5). Extensive beds of water lilies (Nuphar, Nymphaea) are common along both the northern and southern shores of the lake. Water milfoil (Myriophyllum) is the most common submergent macrophyte in Round Lake and is interspersed with Potomogeton spp.in deeper water. Filamentous algal growths were not considered extensive in the lake.

Fish

The Raytheon fathometer data recorded from the 10 cross lake transects were also used to provide a qualitative assessment of the fish community of Round Lake. Echos of fish in the water column appeared on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for the lake.

Total fish abundance in open water areas of Round Lake was estimated at 3.2/1000 feet of fathometer transect. The greatest density of fish (18% total abundance) was at a depth of 11-12 feet (3 meters), with the second greatest density (16%) at 0-1 feet (Figure R6). Fish avoided depths deeper than 13-14 feet (4 meters), the beginning of the thermocline, below which oxygen values quickly fell to less than 1 mg/L. No fish were found below the thermocline. It must be noted, however, that oxygen is only one of many factors controlling fish distributions. Macrophytes such as found at lake depths less than 10 feet provide a prime habitat for both feeding and reproduction and are a major contributing factor to fishery production.

Bathymetric Map and Lake Infilling

The Indiana Department of Natural Resources published a bathymetric map of Round Lake based on a survey of 1925 (Figure R7). Depth contours were constructed at five foot intervals for the lake. The current study constructed an updated bathymetric map for 1990 based on fathometer recordings obtained from 10 lake transects (Figure R8). Following convention established by the 1925 map, five foot contours were constructed for the 1990 map.

A comparison of the depth configurations for 1925 and

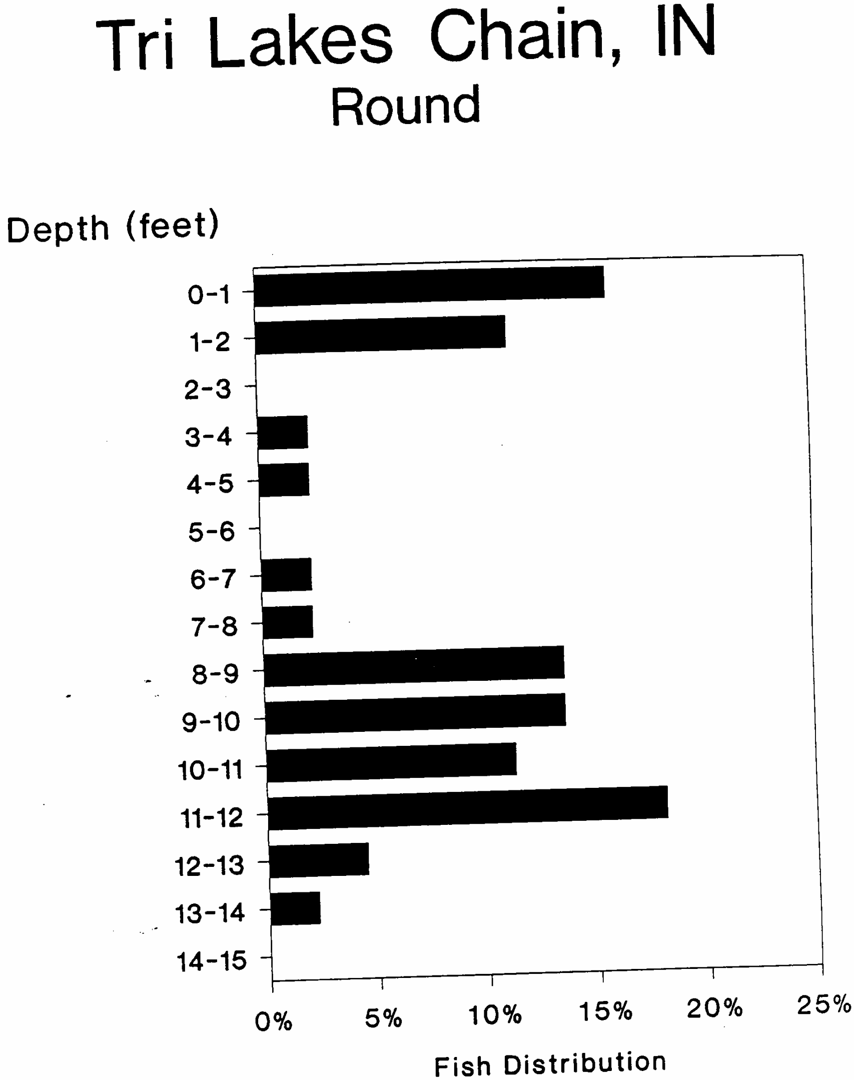


Figure R6. Fish distributions by depth for 1990.

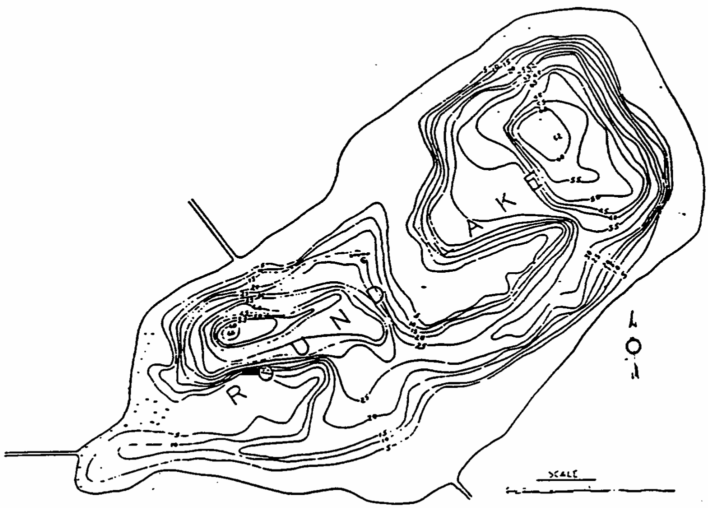


Figure R7. 1925 bathymetric map.

Figure R8. 1990 bathymetric map.

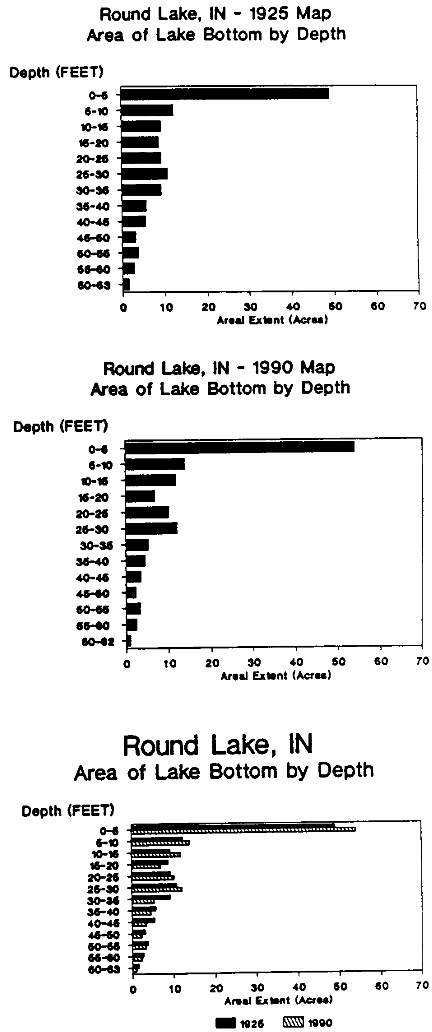


Figure R9. Aerial extent of individual depth contours in 1925 and 1990 expressed in five foot intervals.

Table R12. Percent change in the extent of individual depth contours between 1925 and 1990.

Lake Depth	Round Change
0-5	+ 9.8%
5-10	+ 13.8%
10-15	+ 26.9%
15-20	- 21.6%
20-25	+ 9.7%
25-30	+ 11.1%
30-35	- 43.0%
35-40	- 19.3%
40-45	- 36.4%
45-50	- 25.8%
50-55	- 15.8%
55-60	- 11.1%
60-62	- 33.3%

1990 is provided in Figure R9. The 0-5 foot contour in 1925 comprised approximately 48 acres, an area larger than displayed by an other single contour. The second largest contour was the 5-10 foot contour (12 acres). The deepest section of the lake (greater than 60 feet) was less than 0.5 acres. As in 1925, the 0-5 and 5-10 foot contours displayed the largest aerial extent in 1990, 54 and 13 acres, respectively.

Sedimentation patterns for the past 65 years can be delineated through comparison of the aerial extent of individual contours for 1925 and 1990 (Figure R10, Table R12). The aerial extent of the 10-15 foot contour increased by 26% between 1925 and 1990. The depths showing the second greatest increase in aerial extent were 5-10 and 25-30 feet, which increased by 13% and 11%, respectively. Intervals displaying the greatest loss during the period were 30-35 (43%), 40-45 (36%) and 60-62 feet (33%).

Infilling of nearshore areas was not uniform throughout Round Lake between 1925 and 1990. The most pronounced sedimentation has taken place in the southwestern end of the lake and in the deep basin immediately offshore from the northeastern shore. The latter is near the entry point of watershed discharge pipes.

It is clear that basin sedimentation is strongly controlled by watershed erosion products. Two other contributors to lake infilling, motor boating and shoreline erosion, are possibly contributing factors for the observed pattern of sedimentation in Round Lake but were beyond the scope of the current study.

Sediment Studies

Sediment Core Profiles

A piston coring device equipped with a clear plexiglass tube was used to collect a 90 cm core from the deep water area of Round Lake (Figure R10). Although water content of the Round Lake core remained at greater than 80% throughout its length, values dipped to minimum values between 13 and 30 cm. (Figure R11). Similarly, inorganic content increased from 50-60% below 30 cm to 70-80% above 30 cm depth. It appears that organic content has increased in the upper 10 cm of deposited sediment.

The accumulation of inorganic sediments increased slightly from the mid 1800's to peak core values during the period from approximately 1910 through the early 1930's (Figure R12). Values dropped slightly by the late 1930's and

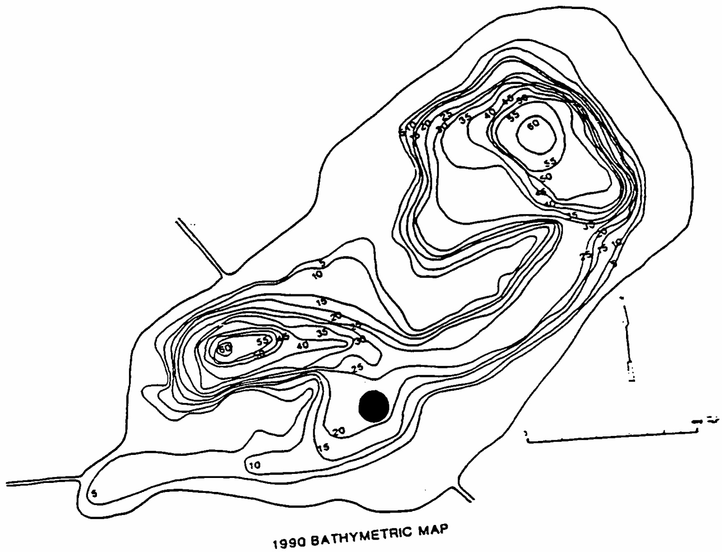


Figure R10. Location of 1990 sediment core.

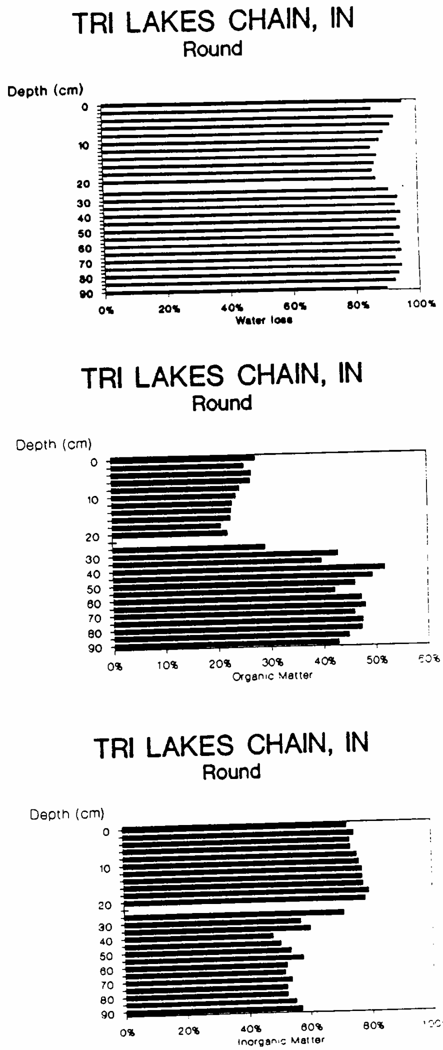


Figure R11. Profile of percent water, organic, and inorganic matter in sediment core.

have remained reasonably consistent to the present.

Although displaying a great deal of interlevel variability, total phosphorus concentrations generally were greatest between 30 and 50 cm and above 10 cm (Figure R13). The profiles for phosphorus and organic matter weakly tracked each other suggesting that some fraction of the phosphorus entering the lake is biologically unavailable. Total phosphorus accumulation rates increased during the first decade of this century and remained reasonably constant until the early 1980's, after which they appeared to increase progressively to the present (Figure R14).

It appears that the major eutrophication period in the recent history of Round Lake was from the early 1910's throught the early 1930's when the delivery of inorganic sediment and total phosphorus increased. The DNR survey of 1968 noted that while there were 14 cottages on the lake in 1925, this number had increased to 129 by 1968. The core data suggest that once established, the impact of residential development remained unchanged.

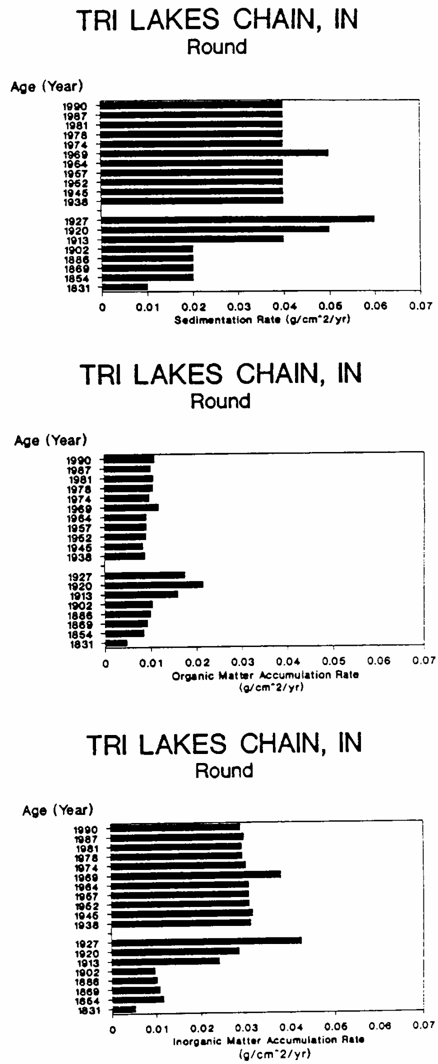
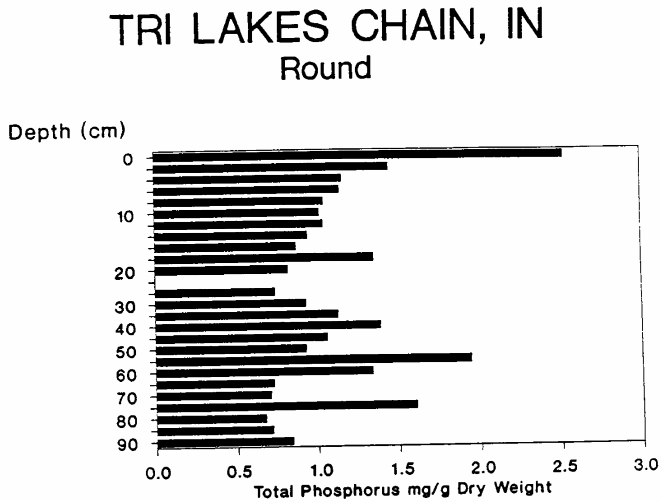


Figure R12. Sedimentation rate and accumulation rates of organic and inorganic matter in sediment core.



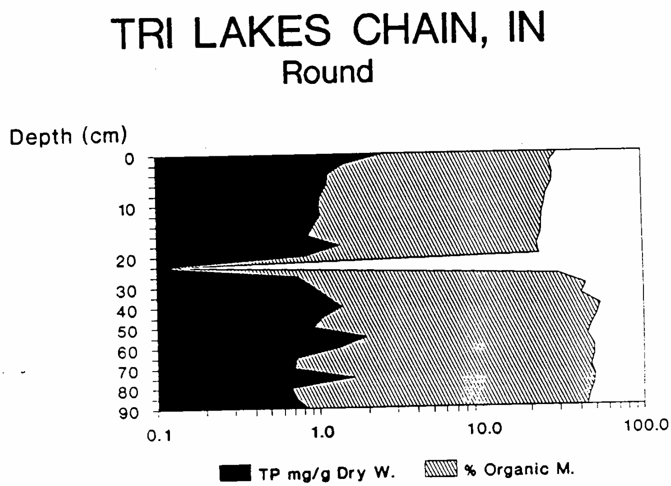


Figure R13. Total phosphorus concentrations and relationship between phosphorus and organic matter in

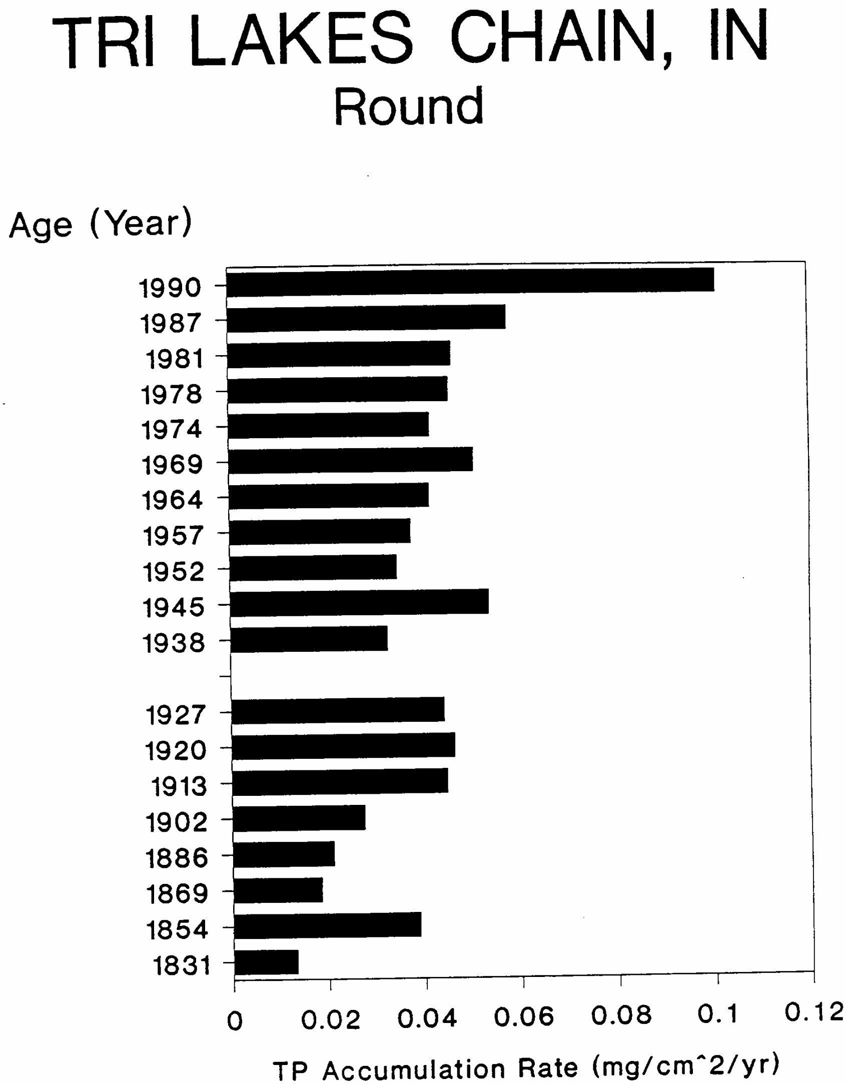


Figure R14. Accumulation rates of total phosphorus in sediment core.

SHRINER LAKE

INTRODUCTION

Shriner Lake, Whitley County, is a 111 acre lake with a maximum and mean depth of 61 feet and 45 feet, respectively. Legal lake level is 906.82 feet and is controlled by a concrete dam 100 feet from the lake in the outlet stream leading to Round Lake. The lake has one permanent inlet, the outlet from Catfish Lake that enters Shriner at the west end. The present study was initiated because of lake residents' concerns regarding observation of siltation associated with delivery of erosion products from the watershed especially during early spring rains.

The current chapter is designed to define the current water quality of Shriner Lake and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on water quality for Shriner Lake. The second section summarizes the water quality analyses conducted as part of the present study and compares values to earlier studies. The third and final section details our sediment studies at Shriner Lake where we were interested in determining the extent of basin infilling in the historical past as well as changes in phosphorus loading to the lake. Management implications of our analysis of past and current water quality will be discussed later in this report.

Historical Water Quality

Historical Database

A total of 9 separate studies were conducted on Shriner Lake between 1925 and 1988 for which data were available (Table S1). The Indiana Department of Conservation constructed a bathymetric map for Shriner Lake in 1925. Collection of water quality data on the lake began in 1930 with the investigation of Will Scott of Indiana University, and D.G. Frey assessed the cisco populations in 1955. Detailed water quality surveys of the lake did not begin until 1965 when the Indiana Department of Natural Resources began surveying the fish community of the lake. The Indiana DNR conducted four studies between 1965 and 1981. The Indiana Department of Environmental Management (IDEM) visited the lake once in the early 1970's to collect water chemistry and biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. Finally, Indiana University recently (1988) collected data on the lake as part of a

Table S1. Chronology of Investigations at Shriner Lake

1925	Indiana Department of Conservation. Construction of bathymetric map for Shriner Lake.
1930	Indiana University. Survey of physical/chemical parameters, phytoplankton and zooplankton. Published by Scott (1931).
1955	David G. Frey. Assessment of status of ciscos in Shriner Lake.
1965	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1974	Indiana Department of Natural Resources. Dissolved oxygen profile and gill netting in "cisco layer" to assess status of cisco population. Published by Gulish (1974).
1975	Indiana Department of Environmental Management. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index.
1978	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1981	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1988	Indiana Department of Environmental Management. Survey conducted by Indiana University of physical, chemical, and biological parameters for construction of IDEM eutrophication index.

Table S2. Historical chemistry.

Shriner Lake Historical Data		July 1965	Aug.1975	Aug.1975	July 1978	June 1981	Aug.1988	Aug.1990
Secchi	feet	19	16	13	14.41	14	24.6	11.3
Mean DO	mg/L	6.84		4.46	6	4.08	3.0	2.9
Alkalinity	mg/L	110		154	119	145	108	120
pH		8.2		8.3	8.3	8.5	7.8	
Conductivity	umhos/cm						270	359
Ca	mg/L	96						
Fe	mg/L	0.1						
K	mg/L	3						
Na	mg/L	9						
Cl	mg/L	14						
SO4	mg/L	18						
Total Phosphorus	mg/L	0	0.05				0.23	0.16
Ortho Phosphorus	mg/L						0.16	
Nitrate-N	mg/L						0.35	0.9
Ammonia-Nitrogen	mg/L						0.79	0.03
Organic N	mg/L						0.44	0.399
Total Kjeldahl N	mg/L							0.429
Chlorophyll	mg/m3							19

water quality assessment grant from IDEM to assess changes in lake trophic state since the 1970's.

Physical/Chemical Parameters

A total of five physical and chemical parameters have been measured at Shriner Lake at a frequent enough intervals to be useful in delineating historical trends (Table S2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As Secchi values have historically been recorded during summer at Shriner Lake, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that Secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months (Table S2). A majority of Secchi values collected for Shriner Lake were for August, and the most recent value, 1988 (24.6 feet), was greater than reported values since at least 1975. On the basis of Secchi data alone, it does not appear that the trophic state of Shriner Lake has changed markedly since at least 1965.

As with Secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal production. A good measure of the degree of eutrophication is provided by the extent of water column anoxia (absence of oxygen) in mid summer (Table S3). Since at least 1981, pronounced water column anoxia has been evident by at least June in Shriner Lake and extends throughout the summer stratified period. Although the historical database is not extensive, it appears that water column anoxia may have become more severe in recent years. Although anoxia was not noted during June 1965, only the upper 30 feet of the water column had oxygen values greater than 1 mg/L in June 1981. In addition, August values suggest an upward vertical expansion of the anoxic zone from 40 feet in 1974 to 23-26 feet for the 1988-1990 period.

Alkalinity is a measure of the carbonate buffering capacity of lakes and can be a useful parameter for assessing changes in watershed delivery of erosion products through human activities. Oscillations in alkalinity values for Shriner Lake since 1964 do not yield any apparent trend that can be related to changes in watershed management practices (Table S2). It is interesting to note, however, that August 1988 was lower than August 1990 and possibly reflects reduced farm runoff during the drought of 1988. Such an interpretation is consistent with the higher Secchi value recorded for the same month reflecting lower algal production.

Table S3. Historical Records of Water Column Anoxia in Shriner Lake, IN

Observation	Initial Depth of <1 mg/L Dissolved Oxygen
June:	
1965	No Anoxia
1981	30 feet
July:	
1978	45 feet
August:	
1975	40 feet
1988	26 feet
1990	23 feet

Although the database is rather limited, total phosphorus concentrations in Shriner Lake fail to display any significant historical trend (Table S2). The remaining physical and chemical parameters measured at Shriner Lake were sampled so infrequently as to be of little value in delineating past trends in water quality.

Microbiology

Neither the Whitley County Health Department nor the Indiana State Board of Health had any historical microbiological data from Shriner Lake.

Phytoplankton

Phytoplankton samples have been collected four times since 1930. Will Scott (1931) collected zooplankton and phytoplankton samples from discrete intervals of the water column during August 1930. The Indiana Department of Environmental Management sampled phytoplankton during August 1975, but detailed data were missing from the departmental files. The final survey of phytoplankton was by Indiana University in August 1988, but details were not provided.

Algal abundance in the surface waters of Shriner Lake during August 1930 was estimated at 920/mL (Table S4). *Fragillaria* was the dominant taxon with *Clathrocystis* and *Anabaena* as the principal subdominants. The presence of several taxa of blue-green algae was suggestive of a moderate degree of production. Algal abundance in surface waters of Shriner Lake for August 1990 was estimated at 4,966/mL and the assemblage was dominated by blue-green taxa. Although the database is limited, the phytoplankton assemblage of Shriner Lake appears to have increased in abundance since 1930, with blue-green algae increasing in importance.

Macrophytes

The macrophyte (aquatic plant) community was examined two times from 1965 to 1978 as part of Indiana Department of Natural Resources fish surveys (Table S5). Plant taxonomic composition was nearly identical for the two surveys. Submergent macrophytes were the most taxonomically diverse plant community with pondweeds displaying the greatest number of species.

The 1965 survey noted that submergents grew to a depth of approximately 20 feet, but that neither macrophytes nor attached algae were considered troublesome in the lake. It

Table S4. Phytoplankton and zooplankton abundances and concentrations of dissolved gases in Shriner Lake in 1930. Table from Scott (1931). Key: (D) depth, (T) temperature, (O) oxygen, (Co_2) carbon dioxide, (Cb) carbonates.

LAKE: SHRINER
Date: S/15/30

Plankton						Dissolved Gases					
Species	0-5	5-10	10-15	15-20		D	T	O	%	CO_2	Cb
Ceratium	4	12	1			S	26.6	5.25		—1.4	23.6
Dinobryum	17	25 2,201	4 42			2	25.3	5.32		—1.0	24.2
Aneura						4	25	5.33		—1.4	24.2
Noltholca			.S								
Polyarthra		38				6	19.6	5.29		—1.2	23.6
Triarthra			2.4								
Hexarthra	17					S	12.7	6.63		0	26.2
Asplancna		4									
Daphnia	14	24	4.8			10	10.5	2.39		1.0	26.S
						12	7.77	1.23		2	26.8
						15	8.8	.14		2	27.6
Diaptomus	6.4	52	8								
Cyclops	1.6	19	2.4			1S	8.6	.06		3.0	2S.0
Nauplii	34	25	10								
Corethra		4									
Melosira		25	25								
Fragillaria	41S	209	46								
Asterionella											
Anabena	132	277	34								
Clathrocystis	341	725	356								
Oscillatoria	S		405								
Lyngbya		2,926	59								

Table S5. Historical data on macrophyte composition.

Shriner Lake
Macrophytes

Species	Common Name	1965	1978
SUBMERGENTS:			
Ceratophyllum demersum	coontail	X	X
Chara spp.	chara		X
Elodea canadensis	elodea	X	X
Myriophyllum exalbescens	water milfoil	X	
Najas flexilis	bushy pondweed	X	
Potomogeton amplifolius	largeleaf pondweed	X	X
Potomogeton crispus	curly leaf pondweed	X	X
Potomogeton foliosus	leafy pondweed	X	X
Potomogeton strictifolius	fine leaf pondweed	X	X
Ranunculus spp.	waterbuttercup	X	
Vallisneria americana	wild celery	X	X
EMERGENTS:			
Eleocharis robbinsii	triangle spike rush		X
Juncus effusus	soft rush	X	
Peltandra virginica	arrow arum	X	X
Polygonum spp.	smartweed	X	X
Pontederia cordata	pickeral weed	X	
Sagittaria latifolia	arrowhead	X	X
Scirpus americanus	bulrush	X	
Typha latifolia	common cattail	X	X
FLOATING LEAVED:			
Brasenia schreberi	watershield	X	X
Nuphar advena	spatterdock	X	X
Nuphar microphyllum	spatterdock	X	
Nymphaea tuberosa	waterlily	X	X

was noted, however, that some chemical treatment has been used in macrophyte trouble spots of the lake and that this limited management practice should be continued. Aquatic macrophytes were not mentioned as problematic in any other fish survey of the Indiana DNR.

Fish

The Indiana Department of Natural Resources surveyed the fish community of Shriner Lake three times between 1965 and 1981. All DNR surveys were based on a combination of electrofishing, gill net, and trap collections, the details of which are presented in Table S6. In addition to the detailed surveys, spot checks for ciscos and trout stocking success were also conducted periodically.

A listing of the individual species caught and the contribution of each to total fish abundance and weight caught during the three DNR surveys are provided in Tables S7 and S8, respectively. Bluegill was the most abundant fish caught in the 1965 and 1978 surveys (20 and 32%) followed by redear (18%) in 1965 and warmouth (17%) in 1978. By 1981, bluegill (7%) was replaced by warmouth (25%) as the most abundant fish of the survey, with lake chubsucker (10%) being the second most abundant. On a weight basis, bluegill (33%) dominated the 1978 survey, and yellow perch (15) dominated the 1981 survey.

Fish stocking into Shriner Lake has been practiced by the Indiana DNR since at least 1954 and was likely conducted by residents prior to that. Fish known to have been stocked into the lake include bluegill, redear, largemouth bass, rainbow trout, smallmouth bass, and rock bass. With the exception of the cisco, no DNR report mentioned trouble with the recreational fishery of the lake.

Ciscos were considered common in Shriner Lake in 1954 but were considered extirpated by 1974. The Indiana DNR fisheries report for 1974 noted that no ciscos had been reported in the lake for at least five years. A 1988 survey also failed to report any ciscos. This fish species requires cold well oxygenated water and is therefore sensitive to deoxygenation of the lower water column associated with increasing eutrophication. The historical cisco data suggest that water quality in Shriner Lake may be have been declining recently. Although the limited historical water chemistry database does not indicate this trend, inherent sensitivity of the cold water fishery to reduced dissolved oxygen conditions in the lower water column may be an early warning indicator of slowly degrading water quality.

Table S6. Historical DNR Fish Sampling in Shriner Lake, IN.

1965	Electrofishing:	4 hrs night
	Gillnets:	5 for 90 hrs = 450 hrs total effort
	Traps:	20 for 45 hrs = 900 hr total effort
1978	Electrofishing:	1.25 hrs night, 1 hr day
	Gillnets:	3 for 96 hrs = 288 hrs total effort
	Traps:	3 for 96 hrs = 288 hrs total effort
1981	Electrofishing:	1 hr night
	Gillnets:	2 for 48 hrs = 96 hrs total effort
	Traps:	3 for 48 hrs = 144 hrs total effort

Table S7. Historical data on fish abundance expressed as a percent of total fish abundance from DNR surveys.

Shriner Lake % Total Fish Abundance	1965	1978	1981
Black Bullhead		0.4	8.2
Black Crappie	0.3	0.3	0.3
Bluegill	20.9	32.1	7
Bowfin	0.2	0.3	0.3
Brown Bullhead	0.1	0.7	4
Brown Trout		1.7	2.6
Grass Pickeral	0.9	2.7	5.4
Lake Chubsucker	1.2	7.4	10.6
Largemouth Bass	13.3	8.4	11
Mimic Shiner	0.1		
Pumpkinseed	11.5	7.8	8.9
Rainbow Trout	1.9		0.1
Redear	18.3	2.9	0.1
Spotted Gar	0.4	0.9	1.2
Spotted Sunfish	7.8	6.6	3.9
Warmouth	12.4	17.5	25.5
Yellow Bullhead	0.1	2.9	2.2
Yellow Perch	10.7	7.4	8.9

Table S8. Historical data on fish weight expressed as a percent of total fish weight from DNR surveys.

Shriner Lake Fish Weight	1978	1981
Black Bullhead	0.3	10.4
Black Crappie	0.2	0.2
Bluegill	33.2	4.7
Bowfin	3.1	1.2
Brown Bullhead	2.9	14.4
Brown Trout	5.7	7.5
Grass Pickeral	2.3	3
Lake Chubsucker	7	8
Largemouth Bass	5.7	11.4
Pumpkinseed	2.6	3.3
Rainbow Trout		1.8
Redear	1.6	0.1
Spotted Gar	3	4
Spotted Sunfish	2.1	1.6
Warmouth	8.4	9.5
Yellow Bullhead	7.8	3.2
Yellow Perch	14.2	15.7

Current Water Quality

The sampling location for current water quality data for Shriner Lake collected on 16 August 1990 is shown in Figure S1, and data for physical and chemical parameters are presented in Table S9.

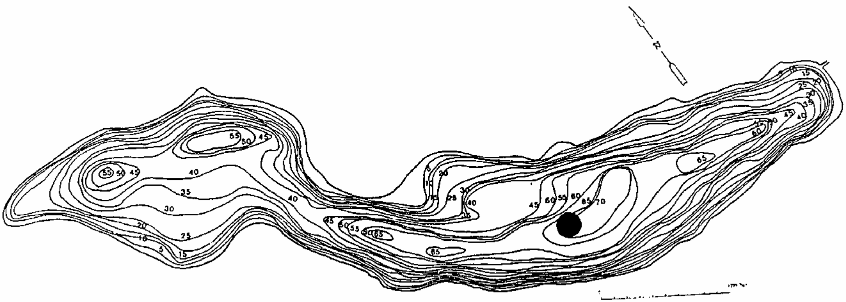
Physical/Chemical Parameters

Temperature. The water columns of northern Indiana lakes greater than approximately five meters deep remain thermally stratified throughout most of the year. As a result of density-temperature relationships, complete mixing of the water column from top to bottom occurs only when water temperature reaches a uniform 4°C, the maximum density of water. This occurs twice a year in temperate lakes (spring and fall) associated with seasonal climatic changes. The length of the mixing period depends on the rapidity of climate change and can vary from a few days to less than a month. Lakes displaying two mixing periods per year are termed dimictic.

During the stratified period, the water column of Indiana lakes is divided into three zones based on temperature-density relationships. The uppermost well mixed zone is termed the epilimnion and extends from the surface to a depth roughly approximating the lower depth of wave action. The lowermost portion of the water column is the hypolimnion, a zone of density-isolated water that mixes with surface waters only during the short mixing periods. The portion of the water column that is transitional between the epilimnion and hypolimnion is termed the metalimnion. That one meter of the metalimnion displaying the greatest temperature change is called the thermocline.

The water column profile clearly demonstrated that Shriner Lake was thermally stratified during August 1990 (Figure S2). The thermocline was between seven and eight meters.

Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).



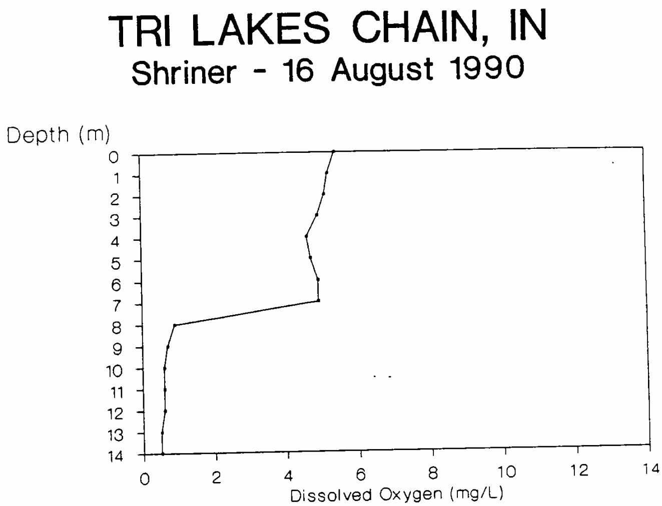
1990 BATHYMETRIC MAP

Figure S1. Sampling location for 1990 survey.

Table S9. Chemistry for 1990.

Shriner Lake		22 Aug.* 1988	16 Aug. 1990
Secchi	feet	24.6	11.3
Mean DO	mg/L	3.0	2.9
Ammonia	mg/L	0.79	0.03
Total Kjeldahl N	mg/L		0.429
Organic-N	mg/L	0.44	0.399
Nitrate	mg/L	0.35	0.9
Total Phosphorus	mg/L	0.23	0.16
Ortho Phosphorus	mg/L	0.16	< 0.01
Conductivity	umho/cm	270.0	359.0
Alkalinity	mg/L	108.0	120.0
Chlorophyll	mg/L	0.0	19.0
pH		7.8	
Temperature	C	14.4	15.3

* Data by Indiana University



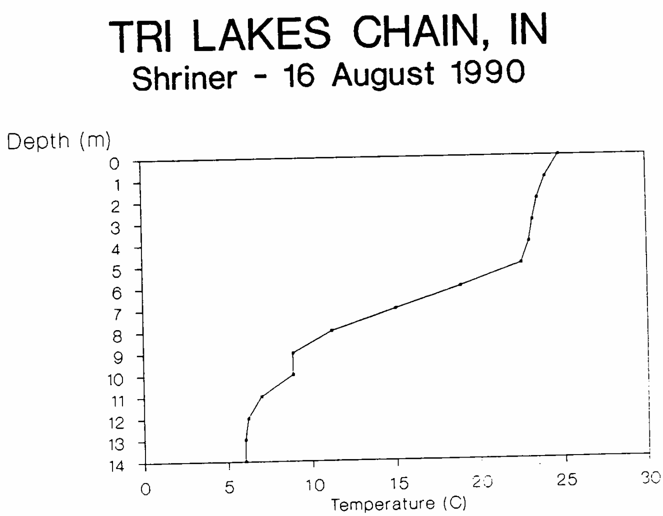


Figure S2. Temperature and dissolved oxygen profiles for Shriner Lake in 1990.

Pronounced water column deoxygenation was noted during August 1990 (Figure S2). As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). The lake was essentially anoxic below a depth of 8 meters.

Mean oxygen values for the water column in August 1990 were less than 5 mg/L suggesting eutrophic conditions (Table S9). Mean water column dissolved oxygen for our 1990 survey (2.9 mg/L) was comparable to that of August 1988 (3.0 mg/L). Historically, Shriner Lake has displayed severe deoxygenation of the water column as early as June or July (Table S3).

Secchi Disc Transparency. As stated earlier in this report, the depth that a Secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the Secchi depth during summer, the more productive (eutrophic) a lake is presumed to be. The 1990 Secchi value (11.3 feet) was the lowest reported in the lake since prior to 1965. It is interesting to note that the 1988 value (24.6 feet) was the greatest clarity reported for Shriner Lake and is likely a reflection of the severe drought of 1988 and the associated reduction in runoff from the watershed. Based on the survey of the 1970's, IDEM observed that only 13% of the state's lakes had Secchi values greater than 10 feet. Thus, the water clarity for Shriner Lake is considered good for a typical Indiana lake.

Nitrogen Forms. The 1990 ammonia value for Shriner Lake (0.03 mg/L) was lower than the only historical value for the lake (August 1988, 0.79 mg/L) (Table S2). Unlike ammonia, nitrite-nitrate nitrogen concentrations were greater during 1990 (0.9 mg/L) than 1988 (0.35 mg/L), the only historical value for this parameter. Although no historical data could be found, Kjeldahl nitrogen values for August 1990 were .429 mg/L. The 1990 ammonia value for the lake is considered extremely low relative to the range found in Indiana lakes, but the nitrite-nitrate are considered intermediate to high suggesting mesotrophic to eutrophic conditions.

Phosphorus Forms. Total phosphorus concentrations were lower during August 1990 (0.16 mg/L) than August 1988 (0.23 mg/L) 1989. Both years were much greater than the 0.05 mg/L reported for 1975. Ortho phosphorus concentrations were below detection in August 1990. Values for the only historical date found, August 1988, were 0.16 mg/L. While orthophosphorus values were considered very low, total phosphorus values were considered indicative of mesotrophic to midly eutrophic lakes. During the 1970's survey, IDEM found that 24% of the state's lakes had total phosphorus values of 0.10-0.50 mg/L.

Nitrogen:Phosphorus Ratios. The ratio of total nitrogen to total phosphorus can be useful in delineating which of these two essential nutrients is limiting primary production in lakes. Numerous authors (Baker et al. 1981, Kratzer and Brezonik 1981, Canfield 1983) have proposed that N:P ratos less than 10 suggest nitrogen limitation, while those greater than 10 suggest phosphorus. The N:P ratio in Shriner Lake was 8.3 in August 1990 and 6.8 during the August 1988 survey of Indiana University. These values suggest that the lake is nitrogen limited at least during part of the summer growing season.

Alkalinity and Conductivity. The alkalinity value reported for August 1990 (120 mg/L) was within the range reported for this parameter (108-154 mg/L) since 1965. It is interesting to note that the 1988 value (108 mg/L) was the lowest value reported since at least 1965 and likely reflects the drought of 1988 and the likely reduction in runoff from the watershed. Although detailed historical data are lacking, a similar parameter, conductivity, was also lower during 1988 (270 umhos/cm) than during 1990 (359 umhos/cm).

Chlorophyll. Chlorophyll is a good estimator of algal biomass in a lake. Chlorophyll concentrations during August 1990 were 19 mg/m^3. There are no historical data for comparison with the 1990 survey. The 1990 chlorophyll value was characteristic of lakes of advancing eutrophication.

IDEM Trophic State Index

Mr Harold BonHomme of the Indiana Department of Environmental Management (IDEM) devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined.

The 1975 eutrophication index for Shriner Lake was calculated by the Indiana Department of Environmental Management as 19, thus assigning the lake to the category of best water quality, Class One. Parameters for the 1990 index calculation were identical to those used for the 1975 index. Based on our August samplings, we have calculated the 1990 IDEM eutrophication index for Shriner Lake as 24 (Table S10). Our calculation is comparable with the 26 calculated

Table S10. IDEM Eutrophication Index for Shriner Lake in 1990.

	Parameter	Value	Eutrophy Points
I.	Total Phosphorus	0.16 ppm	3
II.	Soluble Phosphorus	<0.01 ppm	0
III.	Organic Nitrogen	0.39 ppm	0
IV.	Nitrate	0.90 ppm	3
V.	Ammonia	0.03 ppm	0
VI.	Dissolved Oxygen Saturation @ 5 feet	60%	0
VII.	Dissolved Oxygen (% of water column with >0.1 ppm DO)	81%	0
VIII.	Light Penetration (Secchi Disk)	11.3 feet	0
IX.	Light Transmission (1% at Three Feet)	26 %	4
X.	Total Plankton		
	Vertical Tow (5 ft to Surface)	4,966 cells/mL	4
	Blue-green Dominance	Yes	5
	Vertical Tow (Thermocline)	857 cells/mL	0
	Blue-green Dominance	Yes	5
	> 100,000 cells/mL	No	0
		1990 IDEM Index	24

Table S11. Phytoplankton Composition for Shriner Lake On 16 August 1990.

	Surface	Thermocline
Oscillatoria	3,521	290
Lyngbya	977	120
Anabaena	431	112
Melosira	30	205
Pediastrum	7	130

Surface = algal units/mL calculated from a vertical tow from a depth of five feet to the surface.

Thermocline = algal units/mL calculated from a five foot vertical tow that includes the thermocline.

for August 1988 by W. Jones of Indiana University. While the 1990 value still placed the lake in the category of best water quality, Class One, the 1988 value assigned the lake to Class Two, intermediate water quality.

The phytoplankton assemblage during August 1990 was dominated numerically by Oscillatoria with Lyngbya and Anabaena as the principal subdominants (Table S11). All three taxa were components of the plankton in August 1930 (Table S4) when the assemblage was dominated by Clathrocystis and secondarily by Fragilaria. The overall group composition of the plankton appears to have changed somewhat since 1930 with blue-green algae becoming more of a dominant role.

On the basis of IDEM eutrophication indices alone, it appears that the lake is more productive in 1990 than in 1975. While the 1975 value assigned the lake to Class One, both the 1988 and 1990 values placed the lake at the boundary of Class I (best water quality) and Class II (intermediate water quality). Given that sampling variability, weather patterns, and variability inherent in the IDEM trophic state index may account for differences in index scores of 5 to 10 points, there probably has not been a significant increase in the trophic state index for Shriner Lake since the 1970's. It must also be remembered that the IDEM index is based on parameters collected for the water column in open water sections of the lake, and like all indices, does not include the extent and productivity of aquatic macrophytes. Expanding macrophyte abundance is often associated with reduced nutrient and algal abundance in open water areas as the vegetated littoral zone successfully competes with open water phytoplankton for nutrients (Canfield et al. 1983). We have seen no evidence to suggest that macrophytes in Shriner Lake are extensive enough to influence calculation of the IDEM eutrophication index.

Microbiology

A water sample for fecal coliform and fecal strep analyses was collected on 16 August at the water quality station in the center Shriner Lake. Samples were analyzed within eight hours of collection. The analyses followed the state approved membrane filter procedure and counts have been expressed as most probable numbers (mpn), a standard way of estimating bacterial numbers. The concentration of fecal coliform bacteria was 8 mpn/100 mL, while fecal strep were undetected. All bacteria counts at Shriner Lake during 1990 were well within state standards.

Macrophytes

A raytheon recording fathometer was used to estimate the biovolume of aquatic macrophytes in Shriner Lake. A total of 19 transects spanning the width of the lake were used as the data base. The plant survey was conducted in August 1990 and thus represents summer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of macrophyte infestation throughout the lake system.

The aerial distribution of plant biovolume in Shriner Lake is presented in Figure S3, and the percentage of lake area represented by individual biovolume increments is presented in Figure S4. For convenience, biovolume has been expressed in increments of 20% of water column infestation. Macrophytes generally were restricted to water depths less than 20 feet, thus limiting plant growth in the lake to near shore areas. Given the morphometry of the basin, a large area of the lake bottom (87%) was considered void of vegetation.

Areas of greater than 80% water column infestation were aerially limited to areas immediately along the shore, especially along the middle of the north shore. Only 2% of the lake exhibited greater than 60% plant biovolume.

Our work at other Indiana lakes (Eviston and Crisman 1988, Crisman et al. 1990, Eviston et al. 1990) has demonstrated that the public perceives a macrophyte problem only when plant biovolume exceeds 80% of the water column. Following this reasoning, Shriner Lake does not have a macrophyte problem with the possible exception of the middle of the north shore. The depth distribution of macrophytes is controlled both by basin morphometry and pronounced light limitation below 10 feet water depth. It is suggested further eutrophication of Shriner Lake could result in a pronounced exacerbation of macrophyte problems beyond current levels, but only in nearshore areas.

In addition to looking at the distribution of plant biomass in Shriner Lake, a qualitative survey was made to determine the distribution of the major plant species in the system (Figure S5). Extensive beds of water lilies (Nuphar, Nymphaea) are common at the western end of the lake and along the north shore at the eastern end. Pondweeds (Potomogeton spp.) are the most common macrophyte in near shore areas of Shriner Lake but are replaced in somewhat deeper water by coontail (Ceratophyllum). Filamentous algal growths were extensive along the eastern third of the north shore and the eastern third of the south shore.

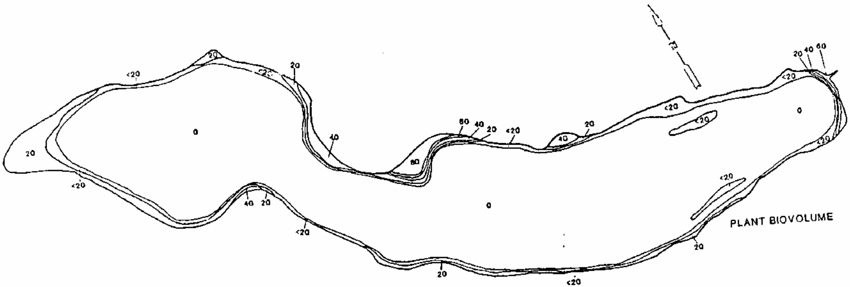


Figure S3. Plant biovolume map for 1990.

Shriner Lake, IN
Percent Plant Biovolume

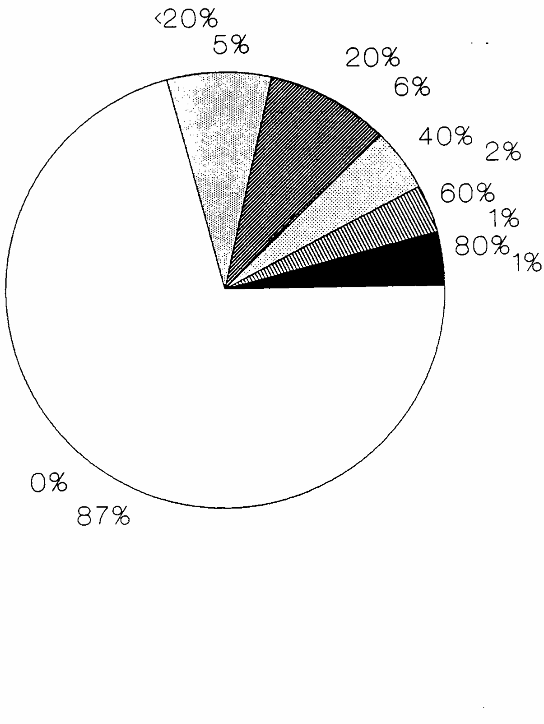


Figure S4. Plant biovolume partitioning for 1990.

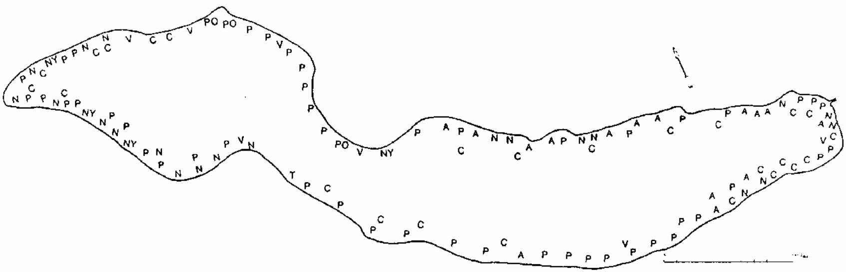


Figure S5. Plant taxa distribution for 1990. Taxa include filamentous algae (A), <u>Ceratophyllum</u> (C), <u>Myriophyllum</u> (M), <u>Nuphar</u> (N), <u>Nymphaea</u> (NY), <u>Pontedaria</u> (PO), <u>Potomogeton</u> (P), and <u>Vallisneria</u> (V).

Fish

The Raytheon fathometer data recorded from the 19 cross lake transects were also used to provide a qualitative assessment of the fish community of Shriner Lake. Echos of fish in the water column appeared on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for the lake.

Total fish abundance in open water areas of Shriner Lake was estimated at 6/1000 feet of fathometer transect. The greatest density of fish (8% total abundance) was at depths of 3-4 feet (1 meter) and 15-16 feet (5 meters), with the second greatest density (7%) at 2-3 feet and 13-14 feet (Figure S6). Fish avoided depths shallower than 3 feet (1 meter), the area of highest temperatures, and deeper than 26-27 feet (8 meters). The latter depth interval was the thermocline, below which oxygen values quickly fell to less than 1 mg/L. Only 8% of the fish tabulated were found below the thermocline. It must be noted, however, that oxygen is only one of many factors controlling fish distributions. Macrophytes such as found at lake depths less than 10 feet provide a prime habitat for both feeding and reproduction and are a major contributing factor to fishery production.

Bathymetric Map and Lake Infilling

The Indiana Department of Natural Resources published a bathymetric map of Shriner Lake based on a survey of 1925 (Figure S7). Depth contours were constructed at five foot intervals for the lake. The current study constructed an updated bathymetric map for 1990 based on fathometer recordings obtained from 19 lake transects (Figure S8). Following convention established by the 1925 map, five foot contours were constructed for the 1990 map.

A comparison of the depth configurations for 1925 and 1990 is provided in Figure S9. The 40-45 foot contour in 1925 comprised approximately 14 acres, an area larger than displayed by an other single contour. The second largest contour was the 35-40 foot contour (11 acres). The deepest section of the lake (greater than 75 feet) was less than 0.5 acres. In contrast, the 0-5 and 45-50 foot contours displayed the largest aerial extent in 1990 (11.5 acres), and the 25-30 foot contour (11 acres) was the second most important contour. The deep water zone (greater than 75 feet) in 1990 had all but disappeared.

Sedimentation patterns for the past 65 years can be delineated through comparison of the aerial extent of

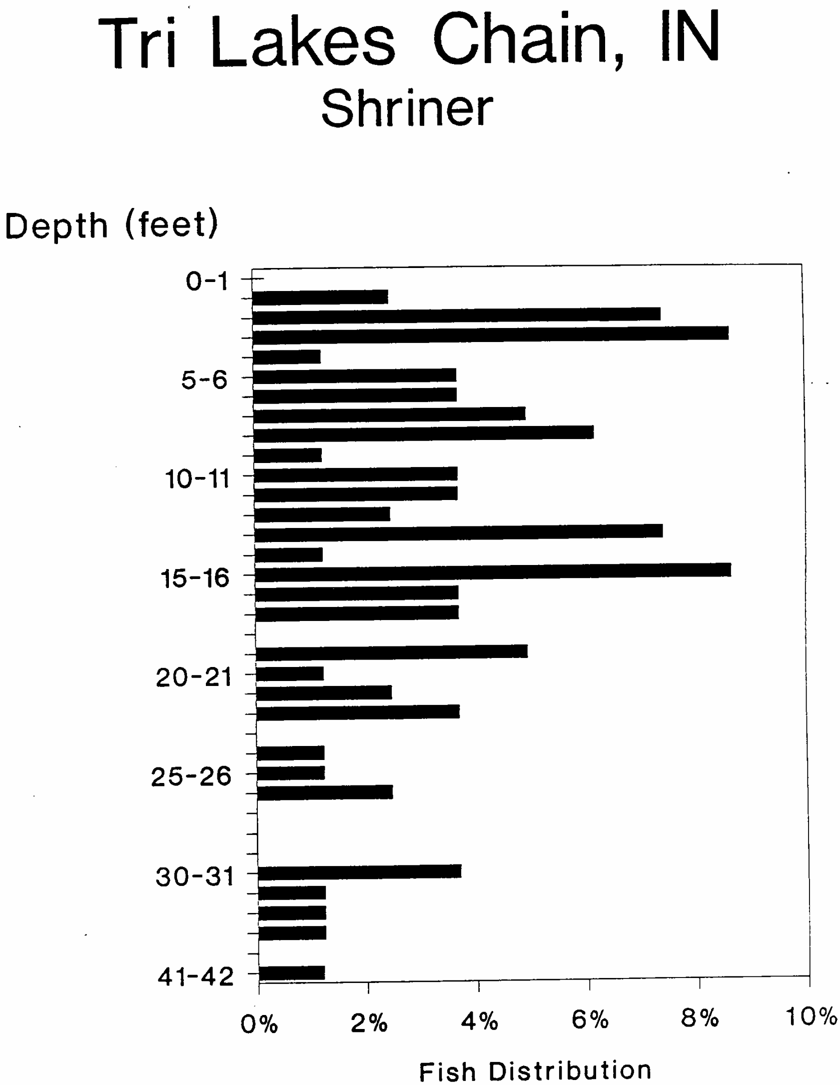


Figure S6. Fish distributions by depth for 1990.

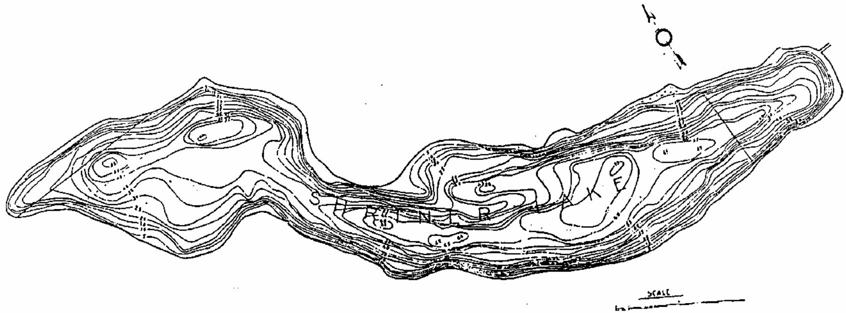
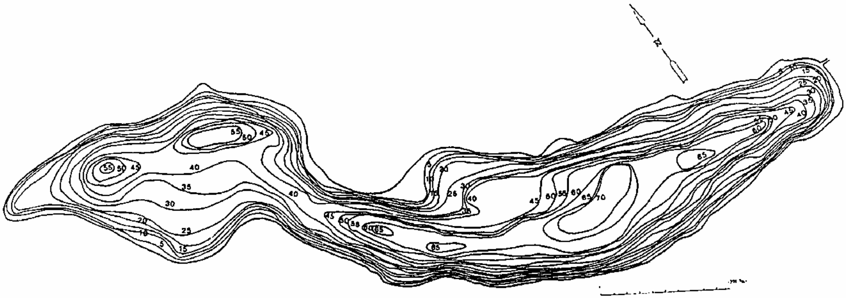
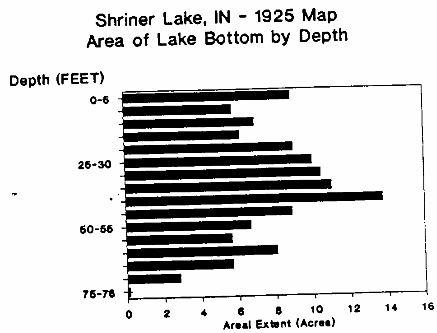


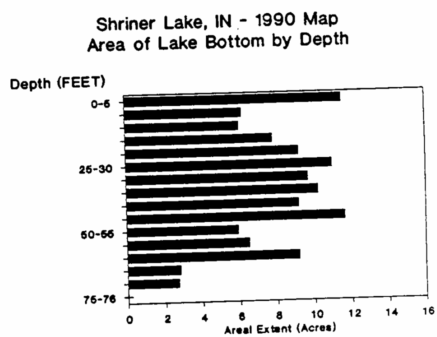
Figure S7. 1925 bathymetric map.



1990 BATHYMETRIC MAP

Figure S8. 1990 bathymetric map.





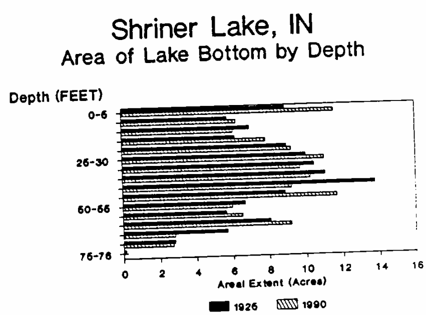


Figure S9. Aerial extent of individual depth contours in 1925 and 1990 expressed in five foot intervals.

Table S12. Percent change in the extent of individual depth contours between 1925 and 1990.

Lake Depth	Shriner Change
0-5	+ 30.3%
5-10	+ 8.6%
10-15	- 12.9%
15-20	- 27.4%
20-25	+ 2.2%
25-30	+ 10.0%
30-35	- 7.6%
35-40	- 7.3%
40-45	- 33.3%
45-50	- 31.5%
50-55	- 10.4%
55-60	+ 14.0%
60-65	+ 13.6%
65-70	- 50.9%
70-75	- 3.6%
75-76	-100.0%

individual contours for 1925 and 1990 (Table S12). The aerial extent of the shallowest depth contour (0-5 feet) increased by 30% between 1925 and 1990. The depths showing the second greatest increase in aerial extent were 55-60 and 60-65 feet, which increased by 14% each. In addition to the loss of areas greater than 75 feet, depth intervals showing the greatest loss in extent were 65-70 (51%), 40-45 (33%) and 45-50 (32%).

Infilling of nearshore areas was not uniform throughout Shriner Lake between 1925 and 1990. The most pronounced sedimentation has taken place in the eastern half of the lake especially from the middle of the north shore outward into the center of the lake. This shore segment was largely undeveloped and marshy during 1925, but has been filled and developed for residences since.

It is clear that basin sedimentation is strongly controlled by watershed erosion products. Two other contributors to lake infilling, motor boating and shoreline erosion, are possibly contributing factors for the observed pattern of sedimentation in Shriner Lake but were beyond the scope of the current study.

Sediment Studies

Sediment Core Profiles

A piston coring device equipped with a clear plexiglass tube was used to collect a 85 cm core from the deep water area of Shriner Lake (Figure S10). Water content of the Shriner Lake core remained at greater than 80% below a depth of 25 cm, but was at 62-80% from that depth to the surface (Figure S11). The more compact nature of the upper 25 cm of the core is clearly related to the fact that the sediments became increasingly inorganic dominated above this depth. Organic content of the sediments shifted from 30-48% below 25 cm to less than 15% above this depth. The idea that the shift to a more inorganic dominated sediment is the result of increased delivery of watershed erosion products is supported by the previously discussed comparison of 1925 and 1990 bathymetric maps.

The accumulation of inorganic sediments increased progressively from the mid 1800's to peak core values during the late 1930's and all of the 1940's (Figure S12). The shift to highly inorganic sediments corresponds to the increased delivery of sediments during the 1930-1950 period. Sedimentation rates of inorganic sediment dropped progressively during the 1950's and remained relatively steady at lower levels during the 1960's and 1970's. It

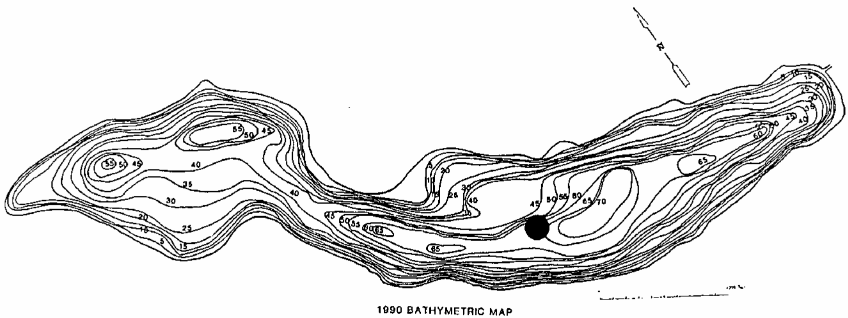
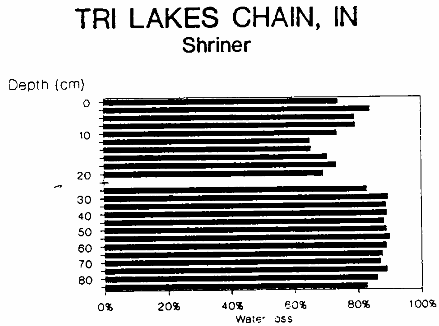
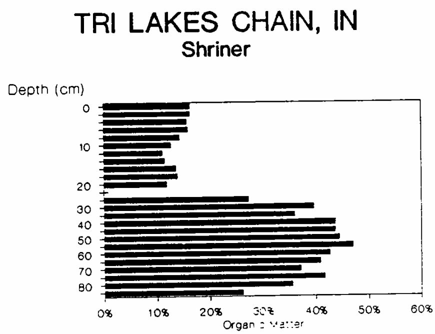


Figure S10. Location for 1990 sediment core.





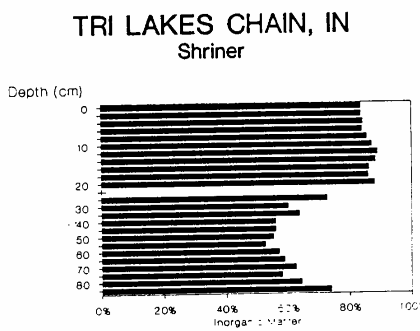
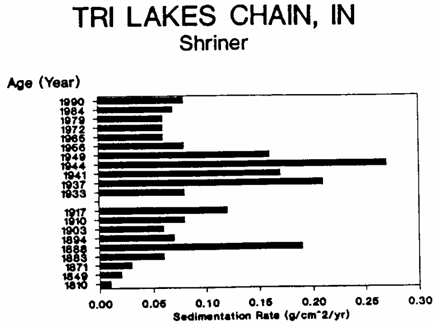
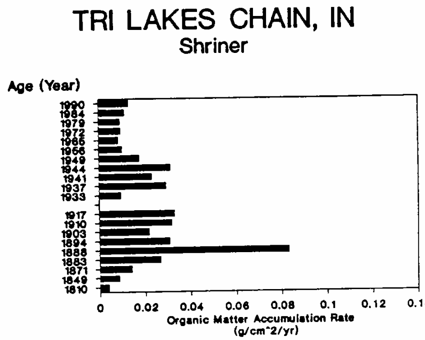


Figure S11. Profile of percent water, organic, and inorganic matter in sediment core.





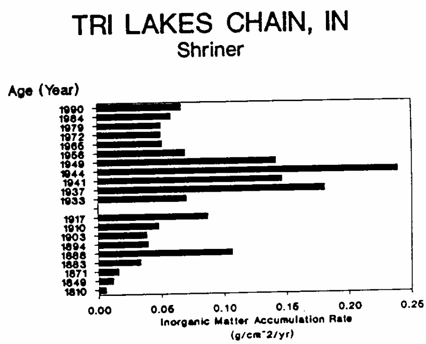
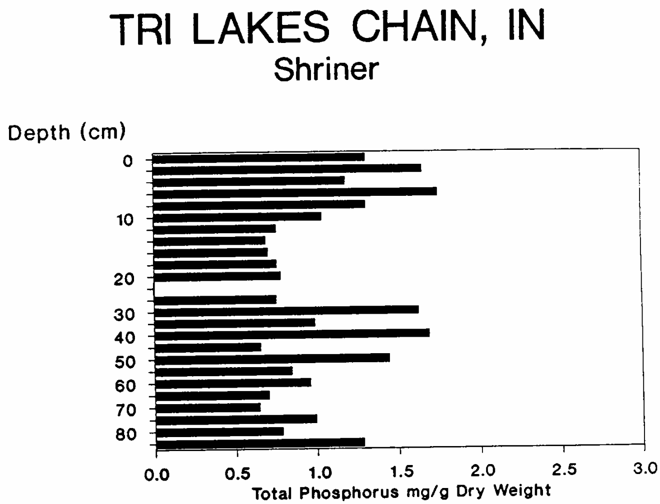


Figure S12. Sedimentation rate and accumulation rates of organic and inorganic matter in sediment core.

appears that accumulation rates of inorganic sediment have been increasing since 1980.

Total phosphorus concentrations were greatest between 30 and 50 cm and above 10 cm (Figure S13). The profiles for phosphorus and organic matter tracked well suggesting that most of the phosphorus entering the lake is biologically available. Total phosphorus accumulation rates increased progressively from the mid 1800's to the turn of the century reflecting progressive land clearance in the watershed, after which they declined until the late 1930's (Figure S14). Coincident with increased delivery of inorganic sediment in the late 1930's and 1940's, phosphorus accumulation rates increased to peak in 1944. This period was followed by a progressive decline in values from 1944 until 1965, after which values have remained relatively constant.

It appears that the major eutrophication period in the recent history of Shriner Lake was during the late 1930's and 1940's when the delivery of inorganic sediment and total phosphorus increased markedly. The DNR survey of 1965 noted that while there were 70 cottages on the lake in 1925, this number had increased to 194 by 1965. Approximately 95% of the cottages in the latter year were occupied year round. Perhaps the greatest development of the shoreline for residential/commercial use was during the 1920's and 1930's, when three hotels and 2 dance halls were operative along the lake shore. The core data suggest that once established, the impact of residential development actually decreased from the late 1940's and into the 1950's, after which it appears to have remained relatively unchanged. Although data could not be found, the recent reduction of residential impact may reflect a reduction in residential nutrient loading to the lake via better attendence to septic systems.



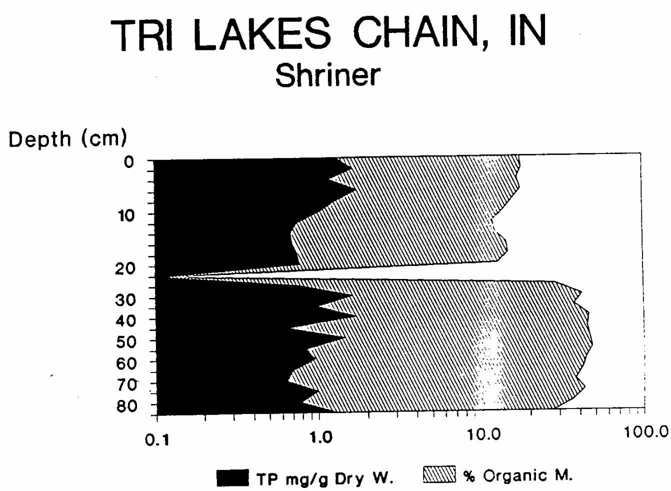


Figure S13. Total phosphorus concentrations and relationship between phosphorus and organic matter in

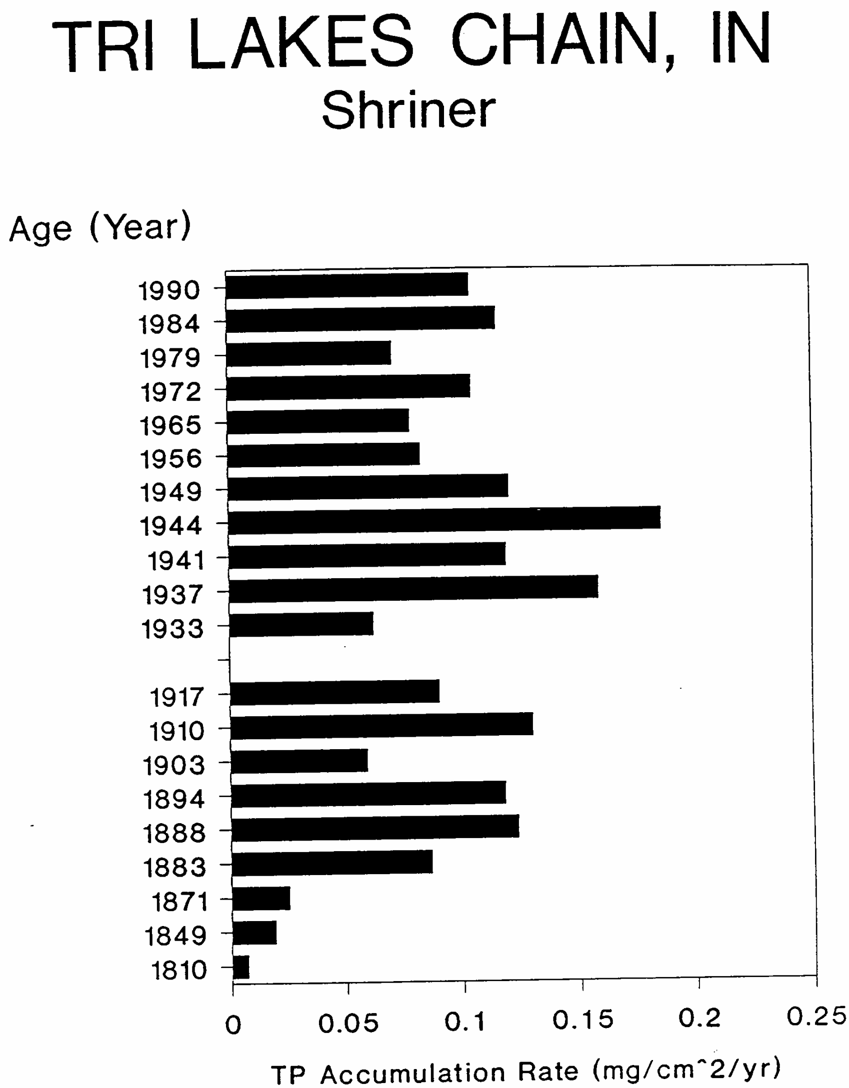


Figure S14. Accumulation rates of total phosphorus in sediment core.

IN LAKE CONCLUSIONS AND RECOMMENDATIONS

WATER QUALITY

Water quality in Big Cedar appears to have changed little since the early 1970's and the lake is still assigned to Class I, the category of best water quality. Although the historical record is sparse, water quality is poorer in Little Cedar and the lake is assigned to the category of intermediate water quality, Class II. Aquatic macrophytes have never been considered problematic in either lake, but algal blooms dominated by blue-green algae are common in Little Cedar. Ciscos, a common cold water fish in 1954, were considered rare by 1975 and extirpated by 1988. The major period of eutrophication in Big Cedar appears to have been prior to the early 1930's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters appear to have changed little since that time. Little Cedar, however, has shown a progressive increase in the annual accumulation rates of both inorganic sediments and total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters appear to have changed little since that time. Little Cedar, however, has shown a progressive increase in the annual accumulation rates of both inorganic sediments and total phosphorus since the time of land clearance in the 1800's, attesting to progressive eutrophication of the basin since European settlement.

Water quality in Round Lake appears to have changed little since the early 1970's. While the lake was assigned to Class II, the category of intermediate water quality, in the 1970's, it was assigned to the category of best water quality, Class I, in 1990. The six point difference in the eutrophication index between the two sampling periods is considered insignificant and likely associated with a change in the extent of aquatic macrophytes in the basin and variability in sampling and weather patterns between years. Aquatic macrophytes have been considered problematic since at least 1968, and algal blooms dominated by blue-green algae are common. Ciscos, a rare cold water fish in 1954, were considered extirpated by 1974. The major period of eutrophication in round Lake appears to have been during the period from the 1910's through the early 1930's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters appear to have changed little since that time.

Water quality in Shriner Lake appears to have changed somewhat since the early 1970's. While the lake was assigned to Class I, the category of best water quality, in the 1970's, it was assigned to the boundary of the category of intermediate water quality, Class II, in 1990. The five point difference in the eutrophication index between the two sampling periods is likely insignificant and associated with interyear variability in parameters comprising the index. Aquatic macrophytes have been considered problematic since at least 1968 except in some nearshore areas where spot treatment with chemicals has periodically been recommended. Ciscos, a common cold water fish in 1954, were considered extirpated by 1974. The major period of eutrophication in Shriner Lake appears to have been during the period from the late 1930's through the 1940's, when annual accumulation rates of total phosphorus and inorganic sediment increased markedly. Deposition rates of both parameters decreased during the 1950's and have changed little since that time.

MACROPHYTES

Macrophytes are considered problematic only in Round Lake, but the DNR has never considered the extent of macrophytes to be detrimental to the lake's fishery. Approximately 39% of the lake's area is characterized by 80 % plant biovolume and thus considered to have a macrophyte problem. A number of techniques can be implemented to control macrophytes (Crisman 1986, Moore and Thornton 1988). Excessive growth can be cut mechanically and removed from the lake. Estimates for this management option in 1987 were $135-300/acre in the Midwest. Although some nutrients can be removed from the lake, this is no permanent solution because roots and seeds are left intact, and finding a suitable site for disposal of the cut material if often difficult. Residents could follow a chemical control program, but this is merely a stop gap measure that can do more harm than good. Estimates for this management option in 1987 were $200-400/acre in the Midwest. Nutrients released from decaying vegetation enter the water column and can promote phytoplankton blooms. Numerous cases exist of excessive chemical treatment that shifts lakes to algal dominance and a whole new range of management problems.

Any plant control at Round Lake must be approached cautiously. The best way to insure that current algal problems are not increased following control of macrophyte problems is to avoid overly zealous complete control of macrophytes in the lake. Until adverse impact to the recreational activities of Round Lake are demonstrated, macrophyte control should not be initiated. Excessive removal of macrophytes from nearshore areas could reduce the kidney effect offered by the vegetated littoral zone and speed the delivery of nutrients to open water areas possibly promoting enhancement of phytoplankton populations

FISH

The most serious fishery problem in the Tri-Lakes chain is the loss of ciscos. This cold water species required cold well oxygenated waters for its survival, and its demise in Indiana lakes is often taken as a sign of advancing eutrophication. Delineation of the causes for the loss of ciscos is complicated through the introduction of game species such as brown trout that may prey on ciscos. Our paleolimnological investigations suggest that although annual accumulations of phosphorus, and presumably eutrophication, changed little during the past 20 years when cisco populations were declining toward extirpation, predator species such as brown trout were stocked regularly. It is suggested that brown trout not be stocked to the lakes until its impact on ciscos can be evaluated fully.

BASIN INFILLING

Our paleolimnological investigations have clearly indicated that periods of increased delivery of inorganic sediment from the watershed are also associated with increased delivery of total phosphorus to promote lake eutrophication. It is recommended that in addition to watershed management practices discussed later, aquatic plants at the mouths of ditches, streams, and drain fields should be left intact as a nutrient and sedimentation barrier. Removal of such plant growth will speed delivery of both parameters into the lakes thus accelerating both basin infilling and eutrophication. With the exception of Round Lake, most sedimentation problems have occurred in deep water, and thus dredging of nearshore areas will have little impact on the magnitude of sediment that has been delivered to the Tri-Lakes chain of lakes.

BLANK

WATERSHED SURVEY

WATERSHED SURVEY

INTRODUCTION AND METHODS

STUDY AREAS

The Tri-Lakes watershed was divided into nineteen subwatersheds, four shoreline areas, the Interlake Wetland Area, and the Outlet Channel area. Each subwatershed and area is presented in the report separately.

The subwatersheds consist of upland areas drained by principal watercourses flowing into the lakes. The shoreline areas contain land adjacent to each of the four lakes where surface water runoff flows directly into the lakes without significant channelization. The Interlake Wetland Area lies between the west ends of Shriner and Cedar Lakes. The Outlet Channel Area contains land that drains into the channel downstream from Round Lake but above the Tri-Lakes water control structure.

The watershed was divided into separate areas for this study to isolate problem areas and correlate land use with stream water quality and individual lake water quality. Each of the subwatersheds or areas was examined separately, and each is presented separately in the report.

LAND USE

Land use is divided into the following four general categories: agricultural, developed, forest, and wetland or pond.

Agricultural land is defined for this report as land either actively or historically used for crop or livestock production, and which has the potential to be used for active agricultural production in the future. Cropland, hay, pasture, fallow fields, and land currently in the Conservation Reserve Program are classified as agricultural.

Land use is classified as developed if the primary use is permanent residences, cottages, commercial establishments, farmsteads, or campgrounds. Vacant lots surrounded by developed area fall into the developed classification. Commercial properties are small and not sufficiently concentrated to be addressed independently of adjacent residential areas. There are no major livestock operations to warrant a separate category for feedlots or farmsteads. Developed areas are concentrated primarily in the shoreline areas with scattered housing and farmsteads in the upland subwatersheds.

Forested lands are found as individual woodlots in the upland subwatersheds or as wooded slopes in ravines or shoreline areas. The few remaining forested areas of the watershed are located on land not historically suitable for agriculture or development.

Wetlands and ponds are grouped together and noted because of their ability to attenuate the effects of surface water runoff into the lakes.

SOILS

The soils in the Tri-Lakes Watershed are primarily of the Morley-Glynwood association. Land formations are gently sloping to steep with well drained to moderately well drained soils formed in glacial till. Land slopes range from 3 to 30 percent. Lakes and marshes occur in the deeper depressions.

This soil association is well suited to trees, although most areas are used for cultivated crops. Erosion is a major hazard in the Morley-Glynwood soil association.

HIGHLY ERODIBLE LAND

The total area of Highly erodible land (HEL) in each subwatershed or area is noted, and the agricultural portion of the HEL is classified as active cropland, fallow cropland, or in the Conservation Reserve Program (CRP).

The following soil types are classified as highly erodible in the Tri-Lakes Watershed:

<u>Whitley County</u>
Blount silt loam, 1 to 4 percent slopes, eroded
Glynwood loam, 3 to 6 percent slopes, eroded
Glynwood loam, 3 to 8 percent slopes, severely eroded
Hennepin loam, 25 to 50 percent slopes
Morley loam 3 to 6 percent slopes, eroded
Morley loam, 6 to 12 percent slopes, eroded
Morley loam, 12 to 20 percent slopes, eroded
Morley loam, 20 to 30 percent slopes, eroded
Morley clay loam, 5 to 12 percent slopes, severely eroded
Morley clay Loam, 12 to 20 percent slopes, severely eroded

<u>Noble County</u>
Morley silt loam, 2 to 6 percent slopes, eroded
Morley silty clay loam, 6 to 12 percent slopes, severely eroded

AGNPS COMPUTER MODEL

The Agricultural Non-Point-Source Pollution Model (AGNPS) is a computer model used to analyze non-point-source pollution and to prioritize potential water quality problems in rural areas. This rainfall event based model uses geographic cells of data units to represent upland and channel conditions in a watershed. Within the framework of these cells runoff characteristics and transport processes of sediment, nutrients, and chemical oxygen demand are simulated for each cell and routed to the outlet. Upland sources of pollution contributing to a potential problem in the lakes can be identified and prioritized for remedial actions to improve water quality.

Three principal agricultural subwatersheds in the Tri-Lakes Watershed were modeled using AGNPS. These subwatersheds are:

Little Cedar Lake 2 Subwatershed
Round Lake 1 Subwatershed
Shriner Lake 2 Subwatershed

Each of the three subwatersheds were modeled individually. Cell size was set at 10 acres to best fit land use patterns in the areas modeled. For purposes of analyzing these subwatersheds the characteristic storm precipitation was set at a 5 year frequency of 3.4 inches in a 24 hour period and a storm energy intensity value of 66.

Cells and flow directions are indicated on the Highly Erodible Land and Land Use Map. Discussion of AGNPS soils loss due to cell erosion appear in this report under the individual subwatershed sections.

The author has reservations regarding the use of the AGNPS Model for analysis of an area with the topographic characteristics similar to those of the Tri-Lakes Watershed. In these glacially formed regions drainage routes are often complex and not well defined. Numerous low ridges and shallow depressions not indicated on topographic maps significantly alter runoff characteristics.

On field inspections to establish watershed and subwatershed boundaries, it was frequently difficult to establish flow direction from shallow depressions on top of dividing ridges.

If input data for the AGNPS Model are collected conscientiously, localized topographic characteristics and land use is identified. Modeling results may then indicate problem areas within the modeled area. Problem areas may be field inspected and priorities for remedial action within the subwatershed established.

The AGNPS Model generates estimates for sediment yield in the subwatershed. Sediment yield is the amount of soil in tons that leaves the downstream end of an AGNPS cell. Sediment yield is computed by adding the amount of sediment entering the cell from upstream cells to the amount of sediment produced by erosion within the cell minus the amount of sediment deposition that occurs within the cell. Cell erosion is the amount of sediment in tons per acre occurring within the individual cell. Cell erosion is a good indicator of where corrective land management practices should be implemented. Cells with cell erosion rates above 2 tons per acre will be noted in the AGNPS article in the subwatershed sections of the report. Complete tabular results of the AGNPS Model are contained in the appendices.

The AGNPS Model also generates estimates for nitrogen, phosphorous, and chemical oxygen demand (COD) losses from individual cells and the resultant concentration of contaminants in runoff discharge from the modeled subwatershed.

Estimates for the total volume of runoff and the peak runoff flow rate in cubic feet per second (cfs) for individual cells and the entire subwatershed area also generated by the AGNPS Model.

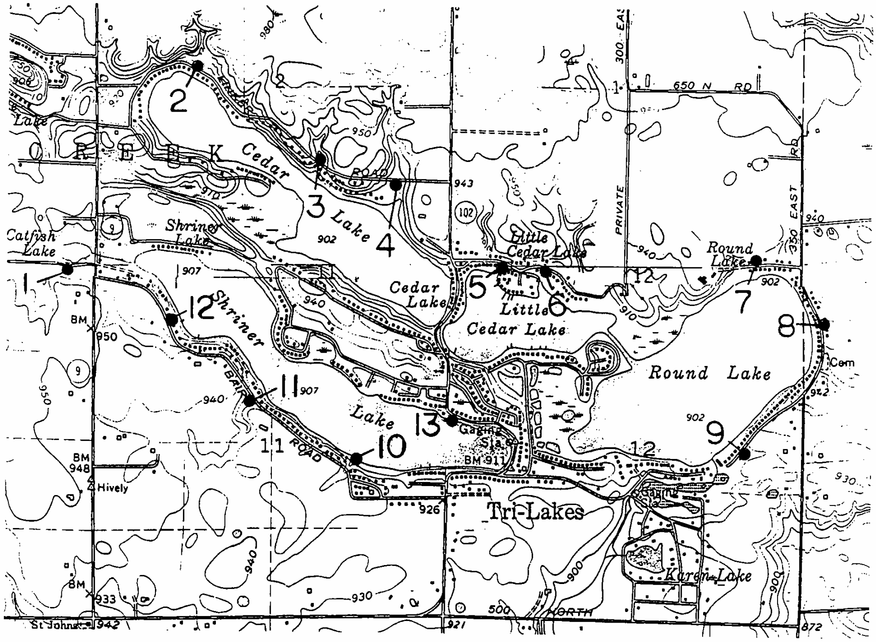
The tabular results may be reviewed with the Highly Erodible Land and Land Use Map to determine the location of cells which may require changes in current land management practices. Discussion in this report will focus on soil loss from individual cell erosion.

STREAM SAMPLES

In order to preserve continuity, laboratory results from stream samples are presented as a part of each subwatershed or area discussion. The actual laboratory test results are included in the appendix of the report.

The inflowing streams or drainage channels into the Tri-Lakes system are all intermittent. A few flow sparingly from springs or tile discharges after periods of wet weather. During the summer months of 1991 all were dry. Several attempts were made to sample the streams after what might be considered ample rainfalls to cause a flush of runoff in the channels, but the streams did not react as expected and contained small almost insignificant flows.

Prior to stream sampling rainfall was monitored. Only after a week of rainfall totalling 2.6 inches and then a rainfall of 1.7 to 2.2 inches in a 12 hour period did the streams flow sufficiently to observe water containing suspended solids.
Streams were sampled on May 31, 1991 after most cropland had been planted and prior to significant emergence of new crops.



1.	Catfish Lake 1 Subwatershed	(CAT-1)
2.	Cedar Lake 4 Subwatershed	(CED-4)
3.	Cedar Lake 6 Subwatershed	(CED-6)
4.	Cedar Lake 7 Subwatershed	(CED-7)
5.	Little Cedar Lake 1 Subwatershed	(LCD-1)
6.	Little Cedar Lake 2 Subwatershed	(LCD-2)
7.	Round Lake 1 Subwatershed	(RND-1)
8.	Round Lake 3 Subwatershed	(RND-3)
9.	Round Lake 4 Subwatershed	(RND-4)
10.	Shriner Lake 1 Subwatershed	(SHR-1)
11.	Shriner Lake 2 Subwatershed	(SHR-2)
12.	Shriner Lake 3 Subwatershed	(SHR-3)
13.	Shriner Lake Shoreline Area	(SHR-R)

Figure W1. Stream Sample Locations

Sample	Sus. Sol. mg/L	COD mg/L	Phos. mg/L	TKN mg/L
CAT-1	136.0	55.0	0.52	3.0
CED-4	84.0	22.0	0.45	2.0
CED-6	86.0	43.0	0.43	1.0
CED-7	80.0	34.0	0.46	<1.0
LCD-1	48.0	39.0	0.69	2.0
LCD-2	216.0	45.0	1.16	5.0
RND-1	138.0	51.0	0.70	3.0
RND-3	10.0	34.0	0.39	3.0
RND-4	44.0	28.0	0.68	3.0
SHR-1	940.0	121.0	1.69	4.0
SHR-2	164.0	55.0	0.78	3.0
SHR-3	48.0	38.0	0.40	4.0
SHR-R	60.0	38.0	0.52	1.0

Sample = Subwatershed (See Figure W1.)
Sus. Sol. = Total suspended solids
COD = Chemical Oxygen Demand
Phos = Total Phosphorous
TKN = Total Kjeldahl Nitrogen

Table W1. Stream Sample Laboratory Results

Runoff was frequently observed along roadsides in the developed shoreline areas during lesser rainfall events, however the primary drainage courses did not appear to react to rainfall as often as expected. The duration and scope of this study was not sufficient to monitor rainfall and resultant stream flows as adequately as necessary to determine solid conclusions regarding peak subwatershed runoff discharges.

Stream samples were not pulled from base flows because for the most part there were no base flows.

Grab samples were collected in acid washed bottles and kept on ice until delivery to Edglo Laboratories in Fort Wayne for analysis.

The samples were analyzed for:

1. Total suspended solids. The total organic and inorganic particulate matter within the water. Suspended solids include sediment which may transport attached nutrients.

2. COD (Chemical Oxygen Demand). The non biological uptake of molecular oxygen by organic and inorganic compounds in water.

3. Total phosphorous. Phosphorous which is immediately available for use by plants and phosphorous compounds which may decompose and become available for plant use.

4. Total Kjeldahl Nitrogen. Free ammonia and organic nitrogen available for plant use.

RECOMMENDATIONS

Recommendations are presented following the discussion of each subwatershed or area.

Recommendations are made considering continued use of private property by human beings, economics, and the existing social and political capabilities for implementing the recommendations. The recommendations set forth will definitely stretch these capabilities. Improvements to the watershed and ultimately the water quality of the lakes will require perseverance and dedication from those committed to the very noble cause of conservation of our earth's resources, and these lakes are treasures among those natural resources.

MAPS

Maps were prepared as an aid to visualizing the watershed and its features. It was necessary to prepare two maps in order to clearly present information. The maps should be referred to as the report is read. The Subwatershed and Topography map contains subwatershed boundaries, drainage channels, elevation contours at an interval of 10 feet, and locations for recommended improvements. The Highly Erodible Land and Land Use Map indicates areas of highly erodible land, current land use, and AGNPS cells. A map indicating property lines and property owners of the larger tracts of land in the watershed was made available to the Tri-Lakes Property Owners Association, however, it is not included in this report. These maps are essential to the understanding and continued management of the watershed.

Tri-Lakes watershed maps were prepared by assembling existing maps of the study area. A composite aerial mylar base map was prepared by Airmaps, Inc. of Elkhart from existing 1980 aerial photography. A contour overlay was created from United States Geological Survey 7.5 Minute Series Topographic Maps of the Tri-Lakes area from the Merriam and Columbia City Quadrangle Maps. Contour intervals are 10 feet. A soils map overlay was prepared from United States Department of Agriculture Soil Conservation Service Soil Survey of Whitley County and of Noble County, Indiana.

Watershed and subwatershed boundaries were established by field inspection of the study area with the topographic map in hand. current land use was verified in the field, and the watershed was flown and photographed at low altitude. Each watercourse was inspected and channel conditions noted. Drainage courses were frequently checked during rainfall events to observe the drainage patterns of the watershed and visible runoff water characteristics.

Watershed, subwatershed, land use, and highly erodible land acreage was measured by planimeter from the prepared maps. Due to the scale of the mapping, areas are not necessarily precise, and measurements are rounded to a whole acre.

SIGNIFICANT NATURAL AREAS

A portion of the northwest shore of Round Land remains relatively unaltered and is considered by the Indiana Department of Natural Resources as a significant natural area. This area is one of three known significant natural area remnants in Whitley County. It was once considered a rich botanical site containing a number of rare aquatic and wetland plant species.

Shriner Lake was described in the Report of the State Geologist in 1900 as one of the prettiest bodies of water in Indiana. "Long and narrow it lies like a priceless emerald of palest green, hidden and guarded by the surrounding hills."

Correspondence and interesting historical information from the Indiana Department of Natural Resources Division of Nature Preserves appears in the Appendix of this report.

WATERSHED LAND USE SUMMARY

CEDAR LAKE WATERSHED

Total watershed land area	394 acres
Agricultural area	138 acres
Developed area	109 acres
Forest area	113 acres
Wetland or Pond area	34 acres
Total highly erodible land (HEL) area	266 acres
Active cropland in HEL area	20 acres

LITTLE CEDAR LAKE WATERSHED

Total watershed land area	516 acres
Agricultural area	357 acres
Developed area	56 acres
Forest area	98 acres
Wetland or Pond area	5 acres
Total highly erodible land (HEL) area	284 acres
Active cropland in HEL area	150 acres

ROUND LAKE WATERSHED (including outlet area)

Total watershed land area	367 acres
Agricultural area	184 acres
Developed area	102 acres
Forest area	43 acres
Wetland or Pond area	38 acres
Total highly erodible land (HEL) area	207 acres
Active cropland in HEL area	48 acres

SHRINER LAKE WATERSHED (including Catfish Lake Watershed)

Total watershed land area	494 acres
Agricultural area	271 acres
Developed area	143 acres
Forest area	42 acres
Open area	19 acres
Wetland or Pond area	19 acres
Total highly erodible land (HEL) area	280 acres
Active cropland in HEL area	40 acres

TOTAL TRI-LAKES WATERSHED

Total watershed land area	1771 acres
Agricultural area	950 acres
Developed area	410 acres
Forest area	296 acres
Open area (non agricultural)	19 acres
Wetland or Pond area	96 acres
Total highly erodible land (HEL) area	1037 acres
Active cropland in HEL area	258 acres

CEDAR LAKE 1 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	39 acres
Agricultural area	32 acres
Developed area	1 acre
Forest area	4 acres
Wetland or Pond area	2 acres
Total highly erodible land (HEL) area	30 acres
Active cropland in HEL area	2 acres
Fallow cropland in HEL area	15 acres
Conservation reserve area	3 acres

DISCUSSION

Cedar Lake 1 Subwatershed lies west of State Road 9 and drains into the Interlake Wetland area via a 36 inch culvert under the highway. This subwatershed has a predominantly permanent grass and forest cover. Surface drainage is buffered by a wetland prior to passing into the Interlake wetland area. The current landowner of most of this area has reforested portions of this subwatershed.

STREAM SAMPLES

Stream samples were not pulled from this subwatershed. Drainage is intermittent and does not flow directly into the lake.

RECOMMENDATIONS

Slopes in this subwatershed are steep, and nearly 75 percent of the area is highly erodible land. This subwatershed should continue to be managed as it is now. The reforested areas will benefit the runoff water quality of this area as trees mature. No recommendations are made for management changes or constructed solutions for Cedar Lake 1 Subwatershed at this time.

INTERLAKE WETLAND AREA

LAND USE SUMMARY

Total subwatershed area	60 acres
Agricultural area	2 acres
Developed area	7 acres
Forest area	29 acres
Wetland or Pond area	22 acres
Total highly erodible land (HEL) area	25 acres
Active cropland in HEL area	2 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	0 acres

DISCUSSION

The Interlake Wetland Area lies east of State Road 9 between Shriner and Cedar Lakes. Cedar Lake 1 Subwatershed drains through a culvert under the highway and into an open ditch at the west end of the area. The open ditch flows east and discharges into a 20 acre wooded swamp. The swamp drains unchannelized into Cedar Lake.

The open ditch was dredged in the summer of 1991. Ditch banks and spoils areas were not seeded until late in the fall. At the time of the field inspection there were erosion problems associated with the ditch reconstruction and with the construction of a pond north of the ditch. Sediment deposits were noted at the ditch outlet in the wooded swamp. The wetland was dry at the time of the inspection. The swamp is not channelized, and it appears to have the ability to buffer runoff prior to entering the lake.

The uplands contain a small low density residential area, but the uplands are predominantly mature forest. A magnificent upland forest area protects the steep slopes of the south side of the Interlake Wetland.

STREAM SAMPLES

Stream samples were not pulled from this area. There is no direct channel into Cedar Lake.

RECOMMENDATIONS

This observer questioned the necessity of dredging the ditch in this area, other than for draining a wetland south of the ditch adjacent to State Road 9. It would benefit the watershed if this wetland were restored. It appears that the agricultural land north of the ditch could still be used if this wetland were restored.

This is a unique natural area and its existence contributes to the health of the Tri-Lakes system. The forested slopes and wetlands should be preserved.

CEDAR LAKE 2 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	8 acres
Agricultural area	5 acres
Developed area	1 acre
Forest area	0 acres
Wetland or Pond area	2 acres
Total highly erodible land (HEL) area	6 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	5 acres
Conservation reserve area	0 acres

DISCUSSION

Cedar Lake 2 Subwatershed is situated between State Road 9 and the west end of Cedar Lake. The area is predominantly covered with grass. In 1991 a pond was constructed which impounds nearly all of the runoff from this subwatershed including runoff from the highway. The pond overflow outlets west of Lynn Street and into a 12 inch pipe which flows into the lake.

STREAM SAMPLES

No stream samples were taken from this small subwatershed. Prior to construction of the pond, runoff from this subwatershed was impounded in a depression and drained into the lake through a field tile.

RECOMMENDATIONS

The areas disturbed by the construction of the pond were reseeded, however vegetative cover is sparse. The disturbed areas are located in highly erodible soils. A good ground cover should be established around the pond.

Sound pond management would be beneficial to the pond and to the Tri-Lakes system by assuring quality overflow water flowing into Cedar Lake.

CEDAR LAKE 3 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	9 acres
Agricultural area	3 acres
Residential area	0 acres
Forest area	6 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	6 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	3 acres

DISCUSSION

Cedar Lake 3 Subwatershed lies north of Linker Road at the northeast end of Cedar Lake. This subwatershed is dominated by a ravine. This ravine is a natural topological feature, and one of a series of similar ravines along the north shores of Cedar, Little Cedar, and Round Lakes. This ravine outlets into a 30 inch pipe north of Linker Road, and the pipe outlets into Cedar Lake.

The upland elevation in this subwatershed ranges from 970 to 980 feet mean sea level. The elevation at the upper reaches of the ravine is 970 feet, and the ravine plunges to 920 feet in the 400 feet distance to Linker Road.

The upland area was actively cropped in 1980. This cropland is now in the Conservation Reserve Program and has a grass cover. The slopes of the ravine are forested. The ravine contains a "V" shaped channel with numerous falls due to fallen trees, root systems and glacial boulders. channel flow is intermittent. this subwatershed is small, however the steep gradient in the bottom of this ravine causes severe erosion.

STREAM SAMPLES

Flow from the Cedar Lake 3 Subwatershed channel was not sampled. It was assumed that stream samples from the similar and adjacent channel in Cedar Lake 4 Subwatershed would be indicative of water quality from this subwatershed.

RECOMMENDATIONS

Discussion of recommendations for Cedar Lake 3, Cedar Lake 4, Cedar Lake 5, and Cedar Lake 6 Subwatersheds are presented in the recommendations section for Cedar Lake 4 Subwatershed.

CEDAR LAKE 4 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	27 acres
Agricultural area	16 acres
Developed area	0 acres
Forest area	11 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	26 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	16 acres

DISCUSSION

Cedar Lake 4 Subwatershed is situated north of the west end of Cedar Lake. Grass covered uplands and a magnificent forested ravine are the predominant features of this area. Intermittent runoff from this subwatershed flows through a 48 inch pipe under Linker Road and into an open channel to the north end of Cedar Lake.

Gradient and the resultant erosion in the bottom of the "V" shaped ravine is severe. A landslide containing at least 100 tons of soil and several trees occurred in 1991. Remnants of previous landslides are apparent in the upper reaches of this ravine.

The upland area of the subwatershed was cropped in 1980. The cropland is now in the Conservation Reserve Program and has a grass cover.

STREAM SAMPLES

The ravine channel flows intermittently. The channel bottom was dry during several field inspections. Small flows occur after periods of wet weather or snow melt, however these small flows appear to transport little or no sediment.

High flows in this ravine after periods of heavy intense rainfall appear to cause significant erosion in the channel bottom. Water from the channel was sampled at Linker Road after a 1.7 inch rainfall in a 12 hour period of time. The following are results from the laboratory analysis:

Parameter	Concentration
Total suspended soils	84.0 mg/L (milligrams per liter)
Chemical oxygen demand (COD)	22.0 mg/L
Total Phosphorus	0.45 mg/L
Total Kjeldahl Nitrogen	2.0 mg/L

RECOMMENDATIONS

The total elevation difference in the channel bottom of these ravines may range from 40 to 70 feet from Linker Road to the upland head of the ravine. The ravines are narrow with precipitous and fragile side slopes. It would be ideal but very expensive to construct rock lined chutes or drop structures in the ravine bottoms to halt the erosion which causes landslides and the continued deepening and widening of the ravines. As an example, to solve the erosion problem along a channel with 40 feet of gradient, eight 5 feet high drop structures would be required. The difficulty of constructing drop structures while trying to preserve sideslopes and trees in these narrow ravines would add expense to the project.

It is not known if the severe erosion damage occurred in these ravines during periods of active cropping of the uplands, or if erosion may subside now that the uplands have grass cover on the cropland. Before a recommendation for construction of drop structures or rock chutes is made for the solution to erosion problems in these small subwatersheds, these ravines should be observed to determine if the change in upland land use will benefit the ravines.

It is recommended that small inexpensive sediment trap detention basins be constructed near the outlet of the ravine. these basins could be monitored as a method of determining the quantity of erosion occurring in the ravines. The basins would also stop heavier sediments from entering the lake.

The uplands in these subwatersheds should not be developed without extensive planning and implementation for control of runoff and erosion. Increased peak runoff discharges associated with development would be devastating to the ravines and result in increased quantities of sediment entering the lake. The upland portions of these subwatersheds should be reforested and left to rehabilitate naturally.

CEDAR LAKE 5 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	33 acres
Agricultural area	10 acres
Developed area	1 acre
Forest area	22 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	27 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	2 acres
Conservation reserve area	8 acres

DISCUSSION

Cedar Lake 5 Subwatershed is located north of Linker Road and Cedar Lake. This area is predominantly forest with grass covered fields in the uplands. The fields were used for crop production in 1980. The cropland is now in the Conservation Reserve Program or fallow. A second tier residential area along the north side of Linker Road extends into this subwatershed.

A ravine with an intermittent channel drains this area into a pipe under the road to an open ditch and into Cedar Lake. Slopes in the lower reaches of the ravine are forested and appear stable, however, the upper reaches and branches of the ravine are still quite active. Channel gradient is not as severe as the gradients in the channels of Cedar Lake 3 and Cedar Lake 4 Subwatersheds.

STREAM SAMPLES

Runoff Flow from the Cedar Lake 5 Subwatershed drainage course was not sampled. It was assumed that the sample pulled from the adjacent Cedar Lake 6 Subwatershed channel would be representative of this area.

RECOMMENDATIONS

Erosion in this ravine does not appear as severe as the erosion in the Cedar Lake 3 and Cedar Lake 4 Subwatershed ravines. Discussion of recommendations for treatment of this subwatershed is presented in the Cedar Lake 4 Subwatershed section.

CEDAR LAKE 6 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	29 acres
Agricultural area	10 acres
Developed area	5 acres
Forest area	14 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	27 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	7 acres
Conservation reserve area	0 acres

DISCUSSION

Cedar Lake 6 Subwatershed lies north of Linker Road north of the Cedar Lake narrows. This area is drained by a forked ravine. A 36 inch pipe carries water under the road and through a yard before opening into an eroded open channel flowing into the lake. There is a visible sediment shoal below water at the outlet of this channel. Springs midway up this ravine cause a slight constant flow in the channel when other subshed ravine watercourses were dry.

The slopes in the ravine are wooded, and the slopes in the lower reaches appear stable. The channel in the lower portions of the ravine near Linker Road also appears stable. The west fork and a branch of the east fork of this ravine are still very active. The northern portion of the main east ravine contains a beautiful stand of beech, walnut and tulip poplars. This ravine gradually diminishes into a wooded depression in the northeast corner of this subwatershed. A field in the upland portion of this area which was farmed in 1980 is now fallow and has a grass cover.

STREAM SAMPLES

The base flow in this channel is fed by springs and is nearly immeasurable. The stream was sampled at Linker Road. The following are the results from the laboratory analyses:

Parameter	Concentration
Total suspended solids	86.0 mg/L (milligrams per liter)
Chemical oxygen demand	43.0 mg/L
Total phosphorous	0.43 mg/L
Total Kjeldahl Nitrogen	1.0 mg/L

RECOMMENDATIONS

This ravine appears more mature and less active than those in the Cedar Lake 3 and Cedar Lake 4 Subwatersheds. However, stream sample laboratory results indicate nearly identical suspended solid concentrations. Discussion of recommendations for treatment of these subwatersheds dominated by ravines is presented in the Cedar Lake 4 Subwatershed section.

An old clay field file discharges into a branch of the west fork of this ravine. It may be possible to provide runoff detention in the upland area drained by the tile and prevent the erosion caused by the tile discharge.

CEDAR LAKE 7 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	90 acres
Agricultural area	60 acres
Developed area	6 acres
Forest area	19 acres
Wetland or Pond area	5 acres
Total highly erodible land (HEL) area	54 acres
Active cropland in HEL area	18 acres
Fallow cropland in HEL area	6 acres
Conservation reserve area	0 acres

DISCUSSION

Cedar Lake 7 Subwatershed is situated north of Linker Road at the east end of Cedar Lake. It is the largest subwatershed on Cedar Lake and it is the only drainage area on this lake that contains cropland currently being farmed. This subwatershed is drained by a ravine. However, this ravine has a broader valley floor and flatter side slopes than the other ravines in the Cedar Lake subwatersheds. In the lower reaches of this ravine the channel is about 3 feet wide, 1 foot deep, and meanders through wetland in the valley bottom. A 12 inch culvert under the road drains this ravine into a similar channel through wetland in the Cedar Lake Shoreline Area. The wetland on the south side of Linker Road is channelized and the flow discharges into the north side of Cedar Lake.

A pond has been constructed near the center of this subwatershed at the head of the ravine. Nearly all surface runoff from the active cropland in the northern half of this area is routed through the pond. This pond appears to attenuate peak runoff flows. The channel in this ravine does not appear to suffer the erosion problems that are common in the other ravines on the north side of the Tri-Lakes.

The ravine slopes are forested and appear stable. The broad valley floor is densely vegetated. The area immediately north of Linker Road could easily be restored as wetland.

STREAM SAMPLES

This stream is intermittent and was sampled at Linker Road. The following are results of the laboratory analyses:

Parameter	Concentration
Total suspended solids	80.0 mg/L (milligrams per liter)
Chemical oxygen demand	43.0 mg/L
Total phosphorous	0.46 mg/L
Total Kjeldahl Nitrogen	<1.0 mg/L

RECOMMENDATIONS

The pond at the head of the ravine apparently has an attenuating effect on runoff from the active cropland in the Cedar Lake 7 Subwatershed. The stream sample laboratory analysis for this subwatershed was similar to that of Cedar Lake 6 which contains no active cropland. The Cedar Lake 7 Subwatershed did not appear to have the peak runoff flow after a severe rainfall event that affected other smaller Cedar Lake subwatersheds which contain ravines. However the water quality of the pond appears poor.

Proper management of active cropland in areas of highly erodible land should be pursued.

The area north of Linker Road could easily be restored as a wetland with stormwater detention capacity. A restored wetland at this location would benefit water quality from this subwatershed flowing into Cedar Lake.

LITTLE CEDAR LAKE 1 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	39 acres
Agricultural area	30 acres
Developed area	1 acre
Forest area	8 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	32 acres
Active cropland in HEL area	21 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	0 acres

DISCUSSION

Little Cedar Lake Subwatershed 1 is located north of the west half of Little Cedar Lake. This subwatershed is 75 percent active cropland, and 65 percent of the active cropland is on highly erodible land. This subwatershed is drained by a grass waterway over a field tile which both discharge into a ravine. The grass waterway is in excellent condition and well maintained, although a small blow-out above the field tile was noted on a field inspection. The outlet of the grass waterway and tile is protected by riprap.

The ravine slopes are wooded and erosion is moderate compared to the ravines in Cedar Lake 3 and Cedar Lake 4 subwatersheds. Although a meander forced by a log is causing substantial bank erosion in the lower reaches of the ravine channel. The channel flows between second tier residences north of Stalf Road and through a 30 inch culvert under the road into the west channel north of the island. The channel is severely shoaled and no longer navigable due to sediment deposited by this drainageway and the outlet of Little Cedar Lake 2 Subwatershed.

The island was probably formed by sediments deposited by runoff from Little Cedar Lake 1 and Little Cedar Lake 2 Subwatersheds.

STREAM SAMPLES

Flows in the Little Cedar Lake 1 Subwatershed channel are intermittent although small flows persist after periods of wet weather due to upland drainage by the field tile. The channel flow appears to peak rather quickly during rainfall events because the watershed is small, drainage courses are well defined, and there is no upland storage. The stream was sampled at Stalf Road and the following are results from the laboratory analysis:

Parameter	Concentration
Total suspended solids	48.0 mg/L (milligrams per liter)
Chemical oxygen demand	39.0 mg/L
Total phosphorous	0.69 mg/L
Total Kjeldahl Nitrogen	2.0 mg/L

The stream appeared to have peaked before samples were pulled. Parameter concentrations in this stream may have been greater prior to the time it was sampled.

RECOMMENDATIONS

Proper management of cropland in highly erodible land is recommended. Although the upland fields of this subwatershed are under no-till cultivation, steep field slopes still showed signs of erosion. It is recommended that these slopes be considered for enrollment in the Conservation Reserve Program, particularly the eroded areas adjacent to the drainage courses near the ravine.

The principal concern in Little Cedar Lake 1 Subwatershed and the other larger agricultural subwatersheds is the high peak runoff flows after heavy rainfall events or rapid snow melt. These peak runoff discharges cause severe erosion in the ravines and channels at the lower end of these subwatersheds. The sediment and contaminants transported by the runoff from the upland area coupled with the sediment caused by erosion in the channels have resulted in significant shoaling in the lakes at the discharge points of these subwatersheds.

There are no feasible sites at the low end of these ravines to construct sediment traps or detention basins large enough to store these runoff discharges. The principal recommendation for solving erosion problems in the ravines and channels of the larger subwatersheds is to provide runoff detention in the uplands. Detention could be in the form of terraces, dry detention basins, wet detention basins, wetlands, or ponds. These types of impoundments can be designed to provide storage for high runoff flows and release those flows from storage at a low flow rate not detrimental to the ravines or channels. The impoundments could also provide some sedimentation of the heavier suspended solids. Properly designed wetlands will provide partial nutrient removal in addition to sedimentation.

Simple changes in land management practices will not alleviate erosion problems in the channels caused by these peak runoff flows because of the high relief and steep drainage course gradients in the Tri-lakes Watershed.

Detention of surface runoff and tile drainage flow is recommended in the upland at the head of the ravine in the Little Cedar lake 1 Subwatershed.

LITTLE CEDAR LAKE 2 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	394 acres
Agricultural area	315 acres
Developed area	11 acres
Forest area	67 acres
Wetland or Pond area	1 acre
Total highly erodible land (HEL) area	214 acres
Active cropland in HEL area	124 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	10 acres

DISCUSSION

Little Cedar Lake 2 Subwatershed is located north of Little Cedar Lake and extends from Stalf Road north into Noble County. This is the largest subwatershed in the Tri-Lakes system. The subwatershed is drained by the Ott Drain, the only legal drain in the watershed. This tile flows through a depression at the County Line Road which was historically a pothole wetland with a watershed containing 120 acres. The wetland is drained and now a part of the Cedar Lake 2 Subwatershed.

Land use in this subwatershed is 80 percent agricultural, and 124 acres of Highly Erodible Land is used for Crop production. There were large dairy and livestock operations active several years ago, however livestock production has diminished and now appears insignificant.

Tile drains, grass waterways, and a farmed drainage course outlet into a branched ravine. This forested ravine has a wide valley floor containing a meandering 10 feet wide channel.Streambank erosion in the channel is severe, and at one point a meander is eroding the ravine slope. The channel continues under Stalf Road via a 54 inch culvert and into Little Cedar Lake east of the island. Shoaling at the channel outlet is severe. The entrance to a channel around the island is not navigable, and several cottages are isolated from the lake.

AGNPS

The Little Cedar Lake 2 Subwatershed was divided into 42, ten acre cells (See the Highly Erodible Land and Land Use Map for cell locations). Cell #41 is the subwatershed outlet cell. The estimated peak runoff flow from the subwatershed is 400 cubic feet per second for a 3.4 inch, 24 hour rainfall event. The total estimated runoff from this subwatershed for this storm is over 50 acre feet, or enough water to fill a five acre pond with 10 feet of water. The AGNPS model estimates that runoff from this particular storm event would deposit nearly 200 tons of sediment in Little Cedar Lake.

Estimated cell erosion rates above 2 tons per acre occurred in over 50 percent of the cells in this subwatershed. Cell erosion rates above 5 tons per acre were estimated to occur in Cell #3, #9, #10, #13, #14, #15, #19, #25, #34, #37, and #42. Priority for land management changes should be given to Cell #30, #32, #33, #34, #37, #38, and #42. These cells are on or adjacent to surface water sources leading directly into Little Cedar Lake.

STREAM SAMPLES

Flows in the Little Cedar 2 Subwatershed channel are intermittent. Flows appear to occur for a longer duration in this channel than others after periods of wet weather, perhaps due to the tile system in this large drainage area. Water in the lower reaches of the channel appears septic during periods of little or no flow. Samples were pulled at Stalf Road and the following are results from laboratory analysis:

Parameter	Concentration
Total suspended solids	216.0 mg/L (milligrams per liter)
Chemical oxygen demand	45 mg/L
Total phosphorous	1.16 mg/L
Total Kjeldahl Nitrogen	5.0 mg/L

RECOMMENDATIONS

Stream sample laboratory results indicate high concentrations of contaminants in the runoff discharge into Little Cedar Lake. This subwatershed also contributes the largest volume of runoff of any of the subwatersheds to the Tri-Lakes system. Large runoff volume coupled with high concentrations of contaminants, visible channel erosion, and lake shoaling cause this subwatershed to be rated first in priority for remedial action.

Refer to the Recommendations in the Little Cedar Lake 1 Subwatershed section of the report for discussion of detention.

It is recommended that ponds or detention basins should be constructed at the head of the ravine branches for storage of peak discharges of runoff water from the tile drains and surface water courses.

The depression at the County Line Road should be restored as a wetland to provide detention and nutrient removal in the upper reaches of the subwatershed.

Two additional sites on the Ott Drain were identified as locations for constructed wetlands to assist in upland detention and sediment and nutrient removal from runoff from the surrounding drainage basins.

Restored or constructed impoundments should be protected from the impacts of runoff from adjacent croplands by vegetated buffer areas.

Sound agricultural land management practices should be pursued in the Highly Erodible Lands of this subwatershed, particularly near the drainage courses and ravine area.

If livestock operations reactivate, efforts should be made to protect drainage courses from feedlot runoff. The tiles underlying the surface drainage courses are direct conduits for nutrients to enter the lake.

LITTLE CEDAR LAKE 3 SUBWATERSHED

LAND USE SUMMARY

Total Subwatershed area	35 acres
Agricultural area	12 acres
Developed area	2 acres
Forest area	20 acres
Wetland or Pond area	1 acre
Total highly erodible land (HEL) area	28 acres
Active cropland in HEL area	5 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	0 acres

DISCUSSION

Little Cedar Lake 3 Subwatershed is situated northeast of the east end of Little Cedar lake. Runoff from the agricultural land in the northern part of the subwatershed drains through a forested area before entering a wooded ravine. The ravine outlets at Stalf Road, and a 24 inch culvert transports water under the road to an open ditch through a yard and into the lake. The ravine channel suffers little erosion compared to other ravines on the north side of the Tri-lakes.

The field in the western part of the subwatershed drains down the face of the slope to the outlet of the ravine. Water from an old tile in this field seeps up through the slope north of Stalf Road.

STREAM SAMPLES

Stream samples were not pulled from this subwatershed.

RECOMMENDATIONS

The forested area of this subwatershed is wet and appears to detain and buffer runoff from the field to the north. The ravine draining this area is in good condition.

Land management changes or detention should be provided to buffer runoff from the field in the western part of the subwatershed. A wetland could easily be constructed in the swale at the south end of the field.

ROUND LAKE 1 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	151 acres
Agricultural area	127 acres
Developed area	5 acres
Forest area	14 acres
Wetland or Pond area	5 acres
Total high erodible land (HEL) area	73 acres
Active cropland in HEL area	42 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	0 acres

DISCUSSION

Round Lake 1 Subwatershed lies north of the northern corner of Round Lake. It is the largest subwatershed on Round Lake and the third largest in the Tri-Lakes watershed. This basin is 85 percent active cropland containing 42 acres of highly erodible soils in crop production. The area of this subwatershed was doubled when a depression South of County Road 650 N was drained by the installation of tile.

The tile draining the depression outlets into a 5 acre pond at the head of a ravine. The pond overflow pipe discharges into the ravine. Another field tile drains the eastern area of the subwatershed and discharges directly into the ravine. The ravine slopes are forested and appear stable. The valley floor is approximately 50 feet wide and contains a meandering channel which suffers streambank erosion. A 30 inch pipe carries the flow under State Camp Road and a garage and discharges into the lake. Shoaling occurs in the lake at the outlet of the pipe.

The emergency spillway serving the pond lies south of the west end of the pond and discharges into a small ravine in the Round Lake Shoreline Area directly to the south. A tile from this pond supplies water to the pond in the Little Cedar Lake 3 Subwatershed. Very little buffer area protects the pond in Round Lake 1 Subwatershed from the adjacent farmed slopes. The water in the pond appeared turbid during every field inspection. Muddy water from the pond discharges into the channel long after the runoff in other channels has clarified.

A number of holes were noticed above broken field tile south of County Road 650 N. Surface drainage courses outletting into the depression appear in poor condition.

AGNPS

The Round Lake 1 Subwatershed was divided into 15, ten acre cells. Cell #15 is the subwatershed outlet cell (See the Highly Erodible Land and Land Use Map for cell locations). The estimated peak runoff flow from the subwatershed is 148 cubic feet per second for the 3.4 inch, 24 hour rainfall event. The model may not accurately reflect the impoundment storage due to the pond in cell #12. The total estimated runoff from this subwatershed for the 5 year storm is over 18 acre feet. The AGNPS model estimates that runoff from this storm event would deposit nearly 246 tons of sediment in Round Lake.

Estimated cell erosion rates above 2 tons per acre occurred in nearly 75 percent of the cells. Cell erosion rates above 5 tons per acre were estimated to occur in cell #3, #5, #8, #10, and #11. Priority for land management changes should be given to cell #10, #11, #12, #13, and #14. These cells are on slopes directly facing the pond or drainage courses leading directly into Round Lake.

STREAM SAMPLES

Flows in the channel are intermittent. Samples were pulled at State Camp Road, and the following are results from laboratory analysis:

Parameter	Concentration
Total suspended solids	138.0 mg/L (milligrams per liter)
Chemical oxygen demand	51.0 mg/L
Total phosphorous	0.70 mg/L
Total Kjeldahl Nitrogen	3.0 mg/L

RECOMMENDATIONS AND CONCLUSIONS

Refer to the Recommendations section in the Little Cedar Lake 1 Subwatershed section of this report for the general discussion of the larger agricultural subwatersheds.

A constructed wetland is recommended downstream from the pond outlet to buffer water from the pond and the east branch of the ravine.

The depression in the center of this subwatershed should be restored as a wetland with detention to assist the pond in removing sediment and nutrients from runoff.

The cropland at the head of the ravine and adjacent to the pond should be enrolled in the Conservation Reserve Program to reduce contaminated runoff from directly entering the ravine and being channeled into the lake. If the depression is restored as a wetland, an adequate buffer area should be provided around it.

Drainage courses should be grassed and tile properly maintained to help alleviate the sediment and nutrient loading in the pond and eventually the lake.

ROUND LAKE 2 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	15 acres
Agricultural area	4 acres
Developed area	10 acres
Forest area	0 acres
Wetland or Pond area	1 acre
Total highly erodible land (HEL) area	15 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	3 acres
Conservation reserve area	1 acre

DISCUSSION

Round Lake 2 Subwatershed is situated northeast of Round Lake. This area is primarily in grass cover. The uplands were cropped in 1980 but now are fallow or in the Conservation Reserve Program. The slopes are predominantly residential yard.

A pond in the center of the subwatershed collects runoff from most of the north half of this drainage area. The east side ditch of County Road 350 E. intercepts runoff from the slopes, and an 18 inch pipe transports flow under the road directly into the lake.

STREAM SAMPLES

Stream samples were not pulled from this subwatershed. A judgement was made that samples from Round Lake 3 Subwatershed would be representative of the Round Lake 2 Subwatershed. Sediment laden runoff from this basin has not been observed during any field inspections.

RECOMMENDATIONS

There is no tilled cropland in this subwatershed. The entire area is in grass cover and appears well managed. This basin is totally Highly Erodible Land, and care should be taken to continue proper management.

ROUND LAKE 3 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	34 acres
Agricultural area	20 acres
Developed area	6 acres
Forest area	8 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	31 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	1 acre
Conservation reserve area	16 acres

DISCUSSION

Round Lake 3 Subwatershed lies east of the lake. Twenty acres of this area was farmed in 1980, however, all cropland is now either fallow or in the Conservation Reserve Program. The balance of the subwatershed is wooded or residential with grass yards.

This basin slopes from the east towards County Road 350 E, and runoff is collected in the road side ditch and carried into the lake through 15 inch and 10 inch pipes.

STREAM SAMPLES

Runoff from this subwatershed is principally shallow concentrated flow collected in the east side ditch of County Road 350 E. Flows are intermittent and stream samples were pulled at the Road from the side ditch. The following are results from laboratory analysis:

Parameter	Concentration
Total suspended solids	10.0 mg/L (milligrams per liter)
Chemical oxygen demand	34.0 mg/L
Total phosphorous	0.39 mg/L
Total Kjeldahl Nitrogen	3.0 mg/L

RECOMMENDATIONS

This subwatershed appears well managed at this time. Approximately 90 percent of this area is Highly Erodible Soils, and care should be taken to continue proper management of this subwatershed.

ROUND LAKE 4 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	32 acres
Agricultural area	24 acres
Developed area	8 acres
Forest area	0 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	20 acres
Active cropland in HEL area	6 acres
Fallow cropland in HEL area	7 acres
Conservation reserve area	0 acres

DISCUSSION

Round Lake 4 Subwatershed is located southeast of Round Lake. Agricultural uplands lie east of County Road 350 E. Two principal drainageways transport runoff under the road to the slopes leading west to the lake. The south drainage way is a swale through a fallow grass field. The north drainage course is a well defined channel through residential yards. The watercourses unite east of Magley Lane, and runoff is transported under the street through a 30 inch pipe into an open ditch to Round Lake.

The agricultural area east of County Road 350 E. contains active cropland and pasture on Highly Erodible Land. Runoff from this area is transported by the well defined north channel.

STREAM SAMPLES

Flow from this subwatershed is intermittent. Samples were pulled at Magley Lane, and the following are results from laboratory analysis:

Parameter	Concentration
Total suspended solids	44.0 mg/L (milligrams per liter)
Chemical oxygen demand	28.0 mg/L
Total phosphorous	0.68 mg/L
Total Kjeldahl Nitrogen	3.0 mg/L

RECOMMENDATIONS

Land management changes should be implemented in the active cropland and pasture in the highly erodible uplands. A constructed wetland or detention is recommended on the drainage courses for sediment and nutrient control in runoff. If development is planned for this area, care should be taken to provide for planning and implementation of temporary and permanent erosion control measures.

SHRINER LAKE 1 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	15 acres
Agricultural area	15 acres
Developed area	0 acres
Forest area	0 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	9 acres
Active cropland in HEL area	4 acres
Fallow cropland in HEL area	5 acres
Conservation reserve area	0 acres

DISCUSSION

Shriner Lake 1 Subwatershed is situated south of the central portion of Shriner Lake. This relatively small subwatershed is entirely agricultural. The area slopes to a corner of Bair Road where surface water is collected by a catch basin on a field tile underlying the subwatershed. The tile transports runoff under Bair Road and outlets directly into the lake. The area of shallow concentrated flow has a grass cover, however the balance of this subwatershed is cropland. Turbid water is frequently observed flowing through the catch basin on the tile draining this area.

STREAM SAMPLES

Flow in the field tile is intermittent. Samples were pulled from the tile outlet at the lake, and the following are results from laboratory analysis:

Parameter	Concentration
Total suspended solids	940.0 mg/L (milligrams per liter)
Chemical oxygen demand	121.0 mg/L
Total phosphorous	1.69 mg/L
Total Kjeldahl Nitrogen	4.0 mg/L

The total suspended solids, COD, and phosphorous concentrations in this subwatershed are higher than those for any other subwatershed.

RECOMMENDATIONS

Proper land management is recommended to prevent the accumulation of suspended solids and associated nutrients in runoff from this area. The Highly Erodible Land in this subwatershed should be enrolled in the Conservation Reserve Program due to the proximity to the lake. A detention basin or constructed wetland with detention is recommended for sediment removal from runoff in this subwatershed if land management changes are not implemented.

SHRINER LAKE 2 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	190 acres
Agricultural area	172 acres
Developed area	3 acres
Forest area	15 acres
Wetland or Pond area	0 acres
Total highly erodible land (HEL) area	97 acres
Active cropland in HEL area	23 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	49 acres

DISCUSSION

Shriner Lake 2 Subwatershed lies southwest of the central area of Shriner Lake. This drainage basin is the second largest in the Tri-Lakes Watershed. The subwatershed is 90 percent agricultural and 55 percent of the farmland is in Highly Erodible Land. Fifty percent of this highly erodible cropland is in the Conservation Reserve Program and only 25 percent is actively cropped.

The farmland west of State Road 9 is drained by field tile which open into a ditch east of the highway. The open ditch drains east into a ravine. The ravine channel flows under Bais Road via a 48 inch by 72 inch pipe arch and continues to the south side of Shriner Lake.

The open drainage ditch in the uplands is not noticeably eroded, however, there are areas where runoff from adjacent fields have cut gullies through the ditch bank. The channel in the ravine is severely eroded due to increased bottom gradient. The ravine slopes appear stable and are primarily covered with scrub growth.

AGNPS

The Shriner Lake 2 Subwatershed was divided into 19 ten acre cells (See the Highly Erodible Land and Land Use Map for cell locations). Cell #11 is the subwatershed outlet cell. The estimated peak runoff flow from the subwatershed is 214 cubic feet per second for a 3.4 inch, 24 hour rainfall event. The total estimated runoff from this subwatershed for this storm is 22 acre feet. The AGNPS model estimates that the 5 year storm event would deposit 60 tons of sediment into Shriner Lake.

Estimated cell erosion rates above 2 tons per acre occurred in 25 percent of the cells. Cell erosion rates above 5 tons per acre were estimated to occur only in cell #6.

Fifty percent of the highly erodible agricultural land in this subwatershed is enrolled in the Conservation Reserve Program. The runoff characteristics from the Shriner Lake 2 Subwatershed compared to those of the Little Cedar Lake 2 and Round Lake 1 Subwatersheds reflect the benefits of land management changes made in the last several years.

STREAM SAMPLES

Flows in the channel are intermittent, though a small base flow continued during wet seasons due to tile drainage in this large subwatershed. Base flow appears clear. The stream was sampled at Bair Road, and the following are results of laboratory analysis:

Parameter	Concentration
Total suspended solids	164.0 mg/L (milligrams per liter)
Chemical oxygen demand	55.0 mg/L
Total phosphorous	0.78 mg/L
Total Kjeldahl Nitrogen	3.0 mg/L

RECOMMENDATIONS

Stream sample laboratory results indicate high concentrations of suspended solids and contaminants in channel flow during periods of peak runoff. The volume of runoff from this large subwatershed coupled with contaminants are cause for concern and place remedial action in this area high on the list of priorities. Refer to the Recommendations in the Little Cedar Lake 1 Subwatershed Section of the report for discussion of detention.

Twenty five percent of the Shriner Lake 2 Subwatershed is currently enrolled in the Conservation Reserve Program. Additional land management practices should be implemented to reduce sediment laden agricultural runoff from directly entering the open ditch in the upland area. A grass filter strip is recommended for installation between the open ditch and the adjacent active cropland. The ravine should also be buffered from direct runoff from agricultural areas.

Detention is recommended for protection of the channel in the ravine from erosion due to peak runoff discharges. A pond with detention capabilities or a series of wetlands also with detention capacity could be constructed in the ravine. A wetland could be constructed in a swale in the southwest corner of the subwatershed east of State Road 9. Detention throughout the upper reaches of the larger subwatersheds would aid the reduction of peak runoff flows.

SHRINER LAKE 3 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	30 acres
Agricultural area	14 acres
Developed area	5 acres
Forest area	9 acres
Wetland or Pond area	2 acres
Total highly erodible land (HEL) area	21 acres
Active cropland in HEL area	2 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	8 acres

DISCUSSION

Shriner Lake 3 Subwatershed lies south of the west end of Shriner Lake. The sloping field north and west of the wooded area was farmed in 1990 but is now in the Conservation Reserve Program. Runoff from the active cropland south of the woodlot is buffered by the woods and a pond prior to entering the drainage course. Runoff is concentrated in a shallow ravine in the woods and transported by a field tile through a residential yard to a 24 inch culvert under Bair Road. An open channel carried flows from the road to the west side of the lake. Detention occurs in a shallow depression in the wooded area and no channel erosion was observed.

STREAM SAMPLES

Parameter	Concentration
Total suspended solids	48.0 mg/L (milligrams per liter)
Chemical oxygen demand	38.0 mg/L
Total phosphorous	0.40 mg/L
Total Kjeldahl	4.0 mg/L

RECOMMENDATIONS

The field which has been removed from active crop production should be seeded with a permanent grass cover. The pond in the upland area would benefit from a buffer area adjacent to the active cropland. Sound residential land management practices should be observed in the developed slopes south of Bair Road.

SHRINER LAKE 4 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	18 acres
Agricultural area	0 acres
Developed area	4 acres
Forest area	0 acres
Grass area	12 acres
Wetland or Pond area	2 acres
Total highly erodible land (HEL) area	16 acres
Active cropland in HEL area	0 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	0 acres

DISCUSSION

Shriner Lake 4 Subwatershed lies north of the west end of Shriner Lake. A ridge separates this drainage basin from the Interlake Wetland Area. This subwatershed is predominantly grass with a low density residential area. A pond north of Poplar Road intercepts the majority of surface runoff from this shed. A tile overflow from the pond outlets into an 18 inch culvert under Poplar Road. Channelized flow continues through a residential yard and into the north side of Shriner Lake. There were no overt signs of erosion in this subwatershed.

STREAM SAMPLES

Stream samples were not pulled from this subwatershed.

RECOMMENDATIONS

Shriner Lake 4 Subwatershed contains no noticeable areas of erosion problems and the pond effectively detains peak runoff discharges. No corrective action for this area is recommended at this time.

CATFISH LAKE 1 SUBWATERSHED

LAND USE SUMMARY

Total subwatershed area	68 acres
Agricultural area	51 acres
Developed area	12 acres
Forest area	1 acre
Wetland or Pond area	4 acres
Total highly erodible land (HEL) area	45 acres
Active cropland in HEL area	5 acres
Fallow cropland in HEL area	0 acres
Conservation reserve area	8 acres

DISCUSSION

Catfish Lake 1 Subwatershed lies west of State Road 9. The entire Catfish Lake drainage basin is regarded as one subwatershed for the purposes of this study, although there are several small subbasins on Catfish Lake. The subwatershed is 75 percent agricultural. A low density developed area is located on steep slopes adjacent to County Road 600 N. Slopes on the north side of the lake are primarily covered with grass.

Surface runoff from the southwest portion of the subwatershed drains through a steep swale used as horse pasture. The pasture appears over grazed and in poor condition. A second shallow ravine collects surface water from the central southern part of the watershed. A pond was constructed in this drainage way in 1991. The pond construction area has not yet been seeded. Both the pond and the pasture area outlet into the south side ditch of County Road 600 N. A 36 inch culvert carries drainage under the road and into Catfish Lake.

The southeast portion of this basin is drained by the west State Road 9 side ditch. The side ditch is paved or riprapped in areas of steep gradient and outlets directly into the channel between Catfish and Shriner Lakes. The east highway side ditch also outlets directly into the channel. No erosion problems were observed in these side ditches.

Erosion associated with construction in this subwatershed has been a problem for a number of years.

STREAM SAMPLES

Parameter	Concentration
Total suspended solids	136.0 mg/L (milligrams per liter)
Chemical oxygen demand	55.0 mg/L
Total phosphorous	0.52 mg/L
Total Kjeldahl Nitrogen	3.0 mg/L

RECOMMENDATIONS

Stream sample laboratory analysis indicate relatively high concentrations of contaminants in runoff from this subwatershed. Although Catfish Lake provides some protection for Shriner Lake, several land use practices could be corrected in this basin. Areas disturbed by construction should be restored and seeded. Livestock should not be pastured in a drainageway leading directly into the lake. The pond constructed in the main drainage ravine will provide some detention for peak runoff discharges, however, this construction site should be restored and vegetated. County road side ditch slopes should also be seeded.

LAKE SHORELINE AREAS

INTRODUCTION

To prevent repetition of the discussion of similar land use and associated problems, the shoreline areas and outlet area will be presented as one subwatershed section in this report. The land use summary is separated by lake or outlet area, and specific problems in an individual lake shoreline area will be noted.

LAND USE SUMMARY

Cedar Lake Shoreline Area

Total shoreline area	99 acres
Developed area	88 acres
Forest area	8 acres
Wetland area	3 acres
Highly erodible land (HEL) area	65 acres
Cedar Lake area	99 acres
Total residences	147
Total business establishments	1

Little Cedar Lake Shoreline Area

Total shoreline area	48 acres
Developed area	42 acres
Forest area	3 acres
Wetland area	2 acres
Agricultural area	1 acre
Highly erodible land (HEL) area	16 acres
Little Cedar Lake area	45 acres
Total residences	138

Round Lake Shoreline Area

Total shoreline area	100 acres
Developed area	56 acres
Forest area	17 acres
Wetland area	27 acres
Highly erodible land (HEL) area	48 acres
Round Lake area	137 acres
Total residences	161
Total business establishments	3

Outlet Area

Total outlet area	35 acres
Developed area	16 acres
Forest area	4 acres
Agricultural area	9 acres
Channel or Wetland area	6 acres
Highly erodible land (HEL) area	20 acres

Residence count included in Round Lake Shoreline Area.

Shriner Lake Shoreline Area

Total shoreline area	173 acres
Developed area	134 acres
Forest area	10 acres
Grass area	12 acres
Wetland area	2 acres
Agricultural area	15 acres
Highly erodible land (HEL) area	108 acres
Shriner Lake area	122 acres
Total residences	251
Total business establishments	8

Shoreline Area Summary

Total Tri-Lakes shoreline area	455 acres
Total Tri-Lakes developed shoreline area	336 acres
Total highly erodible land in shoreline areas	257 acres
Total Tri-Lakes residences	697
Total Tri-Lakes business establishments	12
Total Tri-Lakes Watershed land area	1771 acres

DISCUSSION

The Lake Shoreline Areas consist of land adjacent to the lakes where runoff drains directly into the lakes without significant channelization. These shoreline areas comprise 25 percent of the land area of the Tri-Lakes Watershed. Over 70 percent of the shoreline areas are developed, and 56 percent is Highly Erodible Land.

Shoreline areas differ from the upper subwatersheds in that small rainfall events result in surface runoff directly entering the lakes. These same small rainfall events often do not result in channelized flow entering the lakes from the upper subwatersheds. Channelized flows from the upper subwatersheds although infrequent appear catastrophic. This study was not set up to quantify the difference in runoff between upland subwatershed and shoreline areas. However drainage along roads, driveways, shallow swales, and developed areas was frequently observed entering the lakes during snow melt and rainfall events when there was little or no flow occurring in the principal subwatershed drainage channels.

The topography, the drainage characteristics of developed areas, the proximity of the shoreline areas to the lakes, and the 455 acre size of the shoreline area dictate that land management practices in the shoreline areas should receive primary consideration by residents concerned with water quality in the Tri-Lakes.

A primary concern for most rural lake areas is maintenance of adequate septic systems. Septic system management will not be discussed in this report because a municipal type sanitary sewer collection system and treatment facilities are scheduled for construction for the Tri-Lakes area. Construction related erosion problems however should be a concern during the installation of the new system.

Much literature is available which addresses sound lakeshore property management practices, and property owners should become aware that their actions may directly affect runoff water quality. Although many properties appear well managed, a number of problem areas were observed in the Tri-Lakes Shoreline Areas.

Residential construction and lot grading occurs on slopes without use of temporary erosion control measures or timely permanent erosion control by establishing good vegetative cover.

Grading for drainage along roads, streets, and driveways exposes bare soil in areas of channelized runoff flow causing erosion and transport of sediments or automobile related contaminants directly into the lakes. Slopes for driveways or roads are cut or filled too steeply in places for maintenance of stable slopes and vegetative cover. Gravel roads, roadside shoulders, and pull offs or parking places are frequently muddy and eroded.

Inlets and tiles are used to drain depressions or wet areas. These pipes or tiles are direct conduits into the lake for sediment, nutrient, or contaminant laden runoff water. Of principal concern is the inlet and storm sewer located in the southwest corner of Wilcken Road and Old 102 north of Shriner Lake. A 24 inch storm sewer drains a muddy parking area and discharges directly into Shriner Lake. A vehicle repair shop is located in the drainage basin of the inlet, and numerous old vehicles are parked in the lot. There is no buffer for runoff from this basin.

Depressions and wetlands essential for good water quality are currently being filled. A wetland east of Wilcken Road and Old 102 is used as a trash dump. A wetland contiguous to Shriner Lake has been filled and has been without vegetative cover for the last two years. Several small wetland or depression areas are used as disposal sites for yard wastes and construction debris.

There are numerous open burning areas and campfire sites on slopes or adjacent to the lakes where runoff may leach contaminants directly into the lakes.

Nutrient rich lawn clippings or leaves are disposed of in drainage courses where channelized runoff transports the resultant nutrients into the lakes.

Trash piles on residential lots, in ravines or anyplace in the shoreline areas are not only unsightly but may be a source of contaminants to runoff water.

Dogs confined in kennels or on chains create areas of nutrient rich bare soil. These confinement areas should not be located on slopes adjacent to the lakes, and they should especially not be located in a drainage course where rainfall can flush the site into a lake.

Several lawns are remarkably green and weed free. The use of fertilizers or chemicals on lawns should be eliminated or limited. What goes on a lawn most probably ends up in the lake. The nutrients, especially phosphorous, that stimulate vegetative growth on land also stimulate vegetative growth in the lakes.

Purple Loostrife is used as an ornamental plant on several properties. This plant is a very prolific exotic and will spread and dominate the indigenous plant species of the natural wetland areas around the lakes. According to Indiana law a person may not sell, offer for sale, give away, plant, or otherwise distribute purple loostrife seeds or plants in Indiana.

STREAM SAMPLES

Runoff in the shoreline areas occurs primarily as sheet runoff or shallow concentrated flow. Flow from the storm sewer draining the parking area and surrounding basin north of Shriner Lake was sampled and the following are the results of laboratory analysis:

Parameter	Concentration
Total suspended solids	60 mg/L (milligrams per liter)
Chemical oxygen demand (COD)	38 mg/L
Total phosphorous	0.52 mg/L
Total Kjeldahl Nitrogen	1.0 mg/L

RECOMMENDATIONS

Keep the watershed clean and keep it green. This simple statement summarizes the recommendations for land use adjacent to the lakes. it is important for residents in a lake watershed to understand the vital link between the health of the watershed and the health of the lakes.

Keep the watershed clean. Anything on the watershed that can be dissolved by or transported by runoff waters will probably end up in the lake. The best way to have clean water is to not get it dirty in the first place.

Keep it green. Green means vegetation in the form of grass, trees, bushes, or healthy wetland ecosystems. Vegetation prevents erosion, stores precipitation, reduces runoff, and filters sediments from runoff waters. Vegetation also takes up and stores nutrients preventing them from entering the lakes. Vegetation keeps soils porous so rainfall can soak into the ground and recharge ground water to help keep cold, clean, oxygen rich, springs, flowing into the lakes. Last but not least, vegetation just looks nice. A grove of trees has much more aesthetic value to a lakeshore area than an muddy parking area full of junk vehicles.

Watershed residents should recognize the value of depressions and wetlands for maintaining healthy lakes. These landscape features should be treasured instead of being degraded.

Literature is available addressing sound watershed management practices. A number of recommendations regarding management practices will be reiterated in the Recommendations section of this report.

RECOMMENDATIONS

INTRODUCTION

Before presenting lists of recommendations it may be important to reiterate a number of the characteristics of the Tri-Lakes Watershed as presented in the Watershed Survey. Natural topographic features and land use practices which contribute to water quality problems in the Tri-Lakes system are distributed throughout the twenty five separate subwatersheds, and shoreline areas comprising the Tri-Lakes Watershed. To target a single subwatershed as the primary cause of lake water quality problems neglects to take into account the cumulative effects of the remaining subwatersheds or areas.

Problems in the Tri-Lakes Watershed are both natural and associated with land use. The land area of the watershed is approximately 60 percent Highly Erodible Land (HEL). Twenty five percent of the HEL is currently used as cropland. Over 50 percent of the land area of the watershed is agricultural land, and over 20 percent is developed.

The watershed topography is hilly and drainage course gradients are severe. Erosion from cropland, land use in developed areas, and erosion in drainage course channels contribute sediment to the lakes.

Fifteen acre Shriner Lake 2 Subwatershed discharged runoff containing the highest concentration of contaminants. Little Cedar Lake 2 Subwatershed which contains 394 acres is the single largest subwatershed and discharged runoff with the second worst quality. Little Cedar Lake 2, Shriner Lake 2, Round Lake 1, and Catfish Lake 1 Subwatersheds comprise 45 percent of the land area of the Tri-Lakes Watershed and runoff from these subwatersheds contained the highest concentrations of contaminants.

The lake shoreline areas comprise over 25 percent of the watershed land area, and are at least 55 percent Highly Erodible Land. Runoff in the shoreline areas flows directly into the lakes, and good management of these areas should not be neglected.

SOCIO-POLITICAL RECOMMENDATIONS

In a nation of private property owners conservation and environmentally sound land management is ultimately a local and individual responsibility. Think globally but act locally. Education and awareness are also essential for changing attitudes and establishing an atmosphere for cooperative efforts in the sound management of this watershed. If significant changes in land management or construction projects are undertaken it will be necessary for interested residents to become politically and socially active to successfully implement these changes. Socio-political recommendations are presented below:

1. Open the Tri-Lakes Property Owners Association's membership to residents of the entire watershed. Stress the watershed-lake relationship. Rename the Association to include the word watershed. A possible example for a name is the Tri-Lakes Watershed Environmental Association. The Association does not need to change the activities it is currently involved with; Environmental is a very encompassing word.

2. Establish an environmental committee within the Association to deal with watershed management issues and projects. Invite a representative of the Whitley County Soil and Water Conservation District (SWCD) to serve as an advisor to the committee and a laison for watershed management issues. A member of the committee should attend SWCD Board meetings to learn more about conservation and watershed management issues.

3. Become active in state and national lake management organizations. These organizations are excellent sources of information.

4. Make environmental education of lake and watershed residents a primary goal of the environmental committee. Acquire a library of literature and video resources regarding lake and watershed management. Include an environmental column in the Association newsletter and encourage the local newspapers to publish articles dealing with local watershed and lake related environmental issues.

5. The Association should continue efforts to persuade existing local political agencies to enact and enforce zoning and planning regulations for controlling erosion and pollution. "A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities" by the Highway Extension and Research Project, Indiana Cities and Counties (HERPICC) is a helpful guide for enacting an erosion control ordinance. The model ordinance is available from Purdue University, phone number (317) 494-2164.

6. Consider establishing a political entity by incorporating as a town or by the formation of a conservancy district for purposes of funding and maintaining watershed environmental projects. If such an entity is formed it would be possible to purchase environmentally sensitive properties for preservation.

7. Develop a watershed logo and place attractive professional signs along roadsides bearing the logo and a message such as "Welcome to Tri-Lakes Watershed - Please help keep our land and water clean." Spread the message and get people involved.

LAKE SHORELINE AREA MANAGEMENT RECOMMENDATIONS

When an individual property owner begins taking care of his or her property in an environmentally sound manner, that individual may simply be dismissed as an eccentric. When several property owners start practicing sound management the neighbors may get a little concerned, but no doubt they are witnessing the beginnings of a movement. A movement is what it is going to take to implement lake saving property management practices in the shoreline areas. Remember, the best way to have clean water is to not get it dirty in the first place. Listed below are a number of ways to prevent sediments, nutrients and other contaminants from being transported into lakes by runoff water:

1. Practice temporary and permanent erosion control methods at soil disturbing construction sites. Developing Lands: Erosion and Sediment Control Guide by the Maumee River Basin Commission is a very good source of technical information regarding runoff and erosion control for construction sites. This publication is available from the Maumee River Basin Commission, Room 208, City-County Building, One Main Street, Fort Wayne, IN 46802. The Whitley or Noble County Soil and Water Conservation District Office is also a source of technical assistance regarding erosion control.

2. Place crushed stone or clean gravel on muddy areas of road shoulders, gravel streets, driveways, and parking areas. A stone cover will reduce erosion of fine soil particles in these areas. The Whitley County Highway Department may be a source of assistance on public roads or streets.

3. Minimize paved and impermeable surfaces which prevent rainfall from soaking into the ground.

4. A lake shoreline area is not the place for maintenance and storage of old vehicles. A protective zoning ordinance would be beneficial in dealing with property use which is detrimental to the lake.

5. Erosion in the subwatershed outlet channels in the lakeshore areas should be checked through the use of rock riprap or vegetative cover.

6. Off road recreational vehicles should be operated responsibly and not driven in areas where damage or loss of vegetation will result in soil erosion.

7. Maintain vegetation on steep hills and banks or terrace steep slopes.

8. Maintain and restore natural vegetation buffer zones including trees and bushes along the lake shoreline. These buffer zones filter sediment and nutrients from runoff and provide shade and habitat for wildlife.

9. Recognize the importance of wetlands and depressions in the watershed. Wetlands detain stormwaters and filter sediments and nutrients from runoff. Wetlands and depressions also recharge groundwater which flows into the lakes through clean, oxygen rich spring water. Shoreline wetland areas or shoreline wetland vegetation provides a number of benefits to the lakes. Shoreline wetland vegetation filters runoff water, prevents shoreline erosion, and is an essential element of a healthy lake ecosystem. Do not fill or drain wetlands. Allow the natural establishment of shoreline wetland vegetation along a portion of the lakeshore in front of lake lots. The Interlake Wetland Area and the wetlands on the north and west shorelines of Round Lake are particularly important for maintaining lake water quality. These wetland areas should be preserved.

10. Eliminate or minimize fertilization of lawns. What feeds lawns also feeds lake vegetation. If fertilizer must be applied to lawns have the soil tested (not by a fertilizer company) and apply only what is needed. If at all possible do not use fertilizer containing phosphorous. Apply fertilizer only during the growing season and cut grass at the tall setting on the mower. Do not over water the lawn and cause fertilizers to be leached into the lake.

11. Compost lawn clippings, leaves, aquatic plants, and organic waste in confined areas where runoff will not leach nutrients into the lakes. Recycle nutrient rich compost as fertilizer for gardens and plantings.

12. Do not burn lawn wastes. Confine campfires and burning areas to locations where rainfall will not leach contaminants into the lake. Remove ashes from campfire locations and dispose of them in areas away from the shoreline and safe from runoff.

13. If animals must be confined maintain a vegetative buffer area between the confinement area and the lake. Remove excrement from the area frequently. Do not locate confinement areas on steep slopes near the lake or in drainage courses.

14. Do not feed the ducks. Wild ducks and other waterfowl are natural members of the lake community and should be encouraged to remain in the area through preservation of habitat and nesting areas. However, artificial feeding encourages increased populations of semi-domesticated ducks and large waterfowl populations contribute significant amounts of phosphorous to the lake.

15. Purple Loostrife should be exterminated from the watershed. This non-native plant is a nuisance and will spread to natural wetland areas where it will crowd out indigenous plant species. It can best be eradicated by herbicides or by digging up the entire plant (including the entire root system), placing it in a bag, and burning it.

AGRICULTURAL LAND MANAGEMENT RECOMMENDATIONS

The use of best management practices (BMP's) should be encouraged throughout the agricultural land in the upland subwatersheds. The Tri-Lakes Property Owners Association should contact the Noble and Whitley County SWCD offices to work together on implementing best management practices in the watershed. Areas which could receive priority consideration for BMP's are as follows:

1. Consider the cropland at the head of the ravines in Little Cedar Lake 1, Little Cedar Lake 2, Little Cedar Lake 3 and Round Lake 1 Subwatersheds for enrollment in the Conservation Reserve Program (CRP). Also consider Shriner Lake 1 and Shriner Lake 3 Subwatershed, and the cropland in the lake shoreline areas for enrollment in the CRP. Permanent vegetative cover should be established on newly enrolled fields.

2. Establish grass filter strips along the ditch and ravine in Shriner Lake 2 Subwatershed and establish an adequate vegetative filter around the pond in Round Lake 1 Subwatershed.

3. Consider reforestation of the fallow or CRP fields at the heads of the ravines in Cedar Lake 3, 4, 5, and 6 Subwatersheds.

4. A number of additional grass waterways would be beneficial in the drainage courses of the Little Cedar Lake 1, Little Cedar Lake 2, and Round Lake 1 Subwatersheds, notably in the Round Lake 1 Subwatershed south of County Road 650 N.

5. The AGNPS tabular results should be reviewed by representatives of the Whitley County Soil and Water Conservation District, and individual fields should be further inspected and evaluated for possible best management practices.

CONSTRUCTED SOLUTION RECOMMENDATIONS

Constructed solutions include the construction of ponds or detention basins, sediment traps, and the restoration of construction of wetlands. Constructed solutions should not be relied upon for improving runoff water quality in lieu of sound watershed management practices. However, due to the natural topography and the extensive drainage systems which have altered natural upland detention a number of constructed solutions are recommended for this watershed basin. Recommendations are listed in order of priority based on subwatershed size and runoff quality, although a number of factors including cooperation of land owners and availability of sites may preclude construction according to this recommended order of priority. By no means should the priority lists be regarded as rigid. Particular attention should be given to Little Cedar Lake 2 Subwatershed (394 acres) due to its size and poor runoff water quality. However, no individual subwatershed amounts to more than 25 percent of the entire Tri-Lakes Watershed land area, and decision makers should be cautioned not to depend on a single project to solve lake water quality problems. Discussion of ponds, wetlands and sediment traps and cost estimates appears in this study report in the following section. Recommendations for constructed solutions are as follows:

1. Construct ponds or detention basins with storm runoff storage capacity at the following locations:

   Pond Site 3 in Little Cedar Lake 2 Subwatershed
   Pond Site 6 in Shriner Lake 2 Subwatershed
   Pond Site 2 in Litter Cedar Lake 2 Subwatershed
   Pond Site 1 in Little Cedar Lake 1 Subwatershed
   Pond Site 5 in Round Lake 4 Subwatershed
   Pond Site 4 in Little Cedar Lake 2 Subwatershed

2. Construct or restore wetlands with detention capacity at the following locations:

   Wetland Site 11 in Round Lake 1 Subwatershed
   Wetland Site 1 in Cedar Lake 7 Subwatershed
   Wetland Site 6 in Round Lake 1 Subwatershed
   Wetland Site 8 in Shriner Lake 1 Subwatershed
   Wetland Site 3 in Little Cedar Lake 2 Subwatershed
   Wetland Site 4 in Little Cedar Lake 2 Subwatershed
   Wetland Site 2 in Little Cedar Lake 2 Subwatershed
   Wetland Site 5 in Little Cedar Lake 2 Subwatershed
   Wetland Site 10 in Little Cedar Lake 2 Subwatershed
   Wetland Site 9 in the Interlake Wetland Area
   Wetland Site 12 in Little Cedar Lake 3 Subwatershed

   Wetland sites may be developed concurrently with other constructed solutions because of assistance from the U.S. Fish and Wildlife Service. A U.S. Fish and Wildlife Service representative has inspected the sites listed above and has expressed an interest in the restoration of these areas. See the Agencies and Assistance Programs section for the phone number and address of the U.S. Fish and Wildlife Service.

3. Restore Wetland Site 7 north of Shriner Lake to provide detention and nutrient removal from runoff waters in the basin drained by the inlet and storm sewer. If possible route stormwater runoff through the restored wetland prior to draining into Shriner Lake.

4. Construct and monitor sediment traps at the following locations:

   Sediment Trap 4 in Cedar Lake 6 Subwatershed
   Sediment Trap 3 in Cedar Lake 5 Subwatershed
   Sediment Trap 2 in Cedar Lake 4 Subwatershed
   Sediment Trap 1 in Cedar Lake 3 Subwatershed
   Sediment Trap 5 in Little Cedar Lake 2 Subwatershed

WATERSHED CONSTRUCTION PROJECTS

SEDIMENT BASINS

A sediment basin or trap is a small pond constructed in a drainage channel and designed to reduce the velocity of runoff water as it passes through the basin. As runoff water velocity is reduced suspended sediment particles settle to the bottom of the basin and remain trapped in the basin. The sediment trap thus prevents a certain amount of sediment from entering the lake.

The effectiveness of a sediment basin depends on its size. A larger basin allows for a longer residence time for runoff water which results in increased settlement of suspended solids. Due to site space restrictions sediment basins generally can not be designed to completely remove all sediment from runoff water in a channel. However even a small sediment trap can remove larger particulate matter and stop the migration of sand along the bottom of a channel, thus preventing some sedimentation of the lakes.

Sediment basins can be simple to construct, and may only consist of a wide deep spot excavated in a channel. In the ravine areas of the Tri-Lakes Watershed, sediment basins may consist of an excavation and a dike with a simple two stage outflow structure.

It is important to locate sediment basins where they can be easily inspected and maintained. Trapped sediments should be removed from the basins periodically to ensure the efficient operation of the sediment basins.

PONDS OR DETENTION BASINS

The Tri-Lakes Watershed contains numerous suitable sites for construction of ponds or detention basins. The natural water courses which drain the subwatersheds have created ravines or shallow valleys with relatively steep channel gradients. Earth embankment dams may be constructed across these ravines or valleys creating the impoundments. Excavation for the embankment should be in the impoundment area to enlarge the storage capacity of the pond.

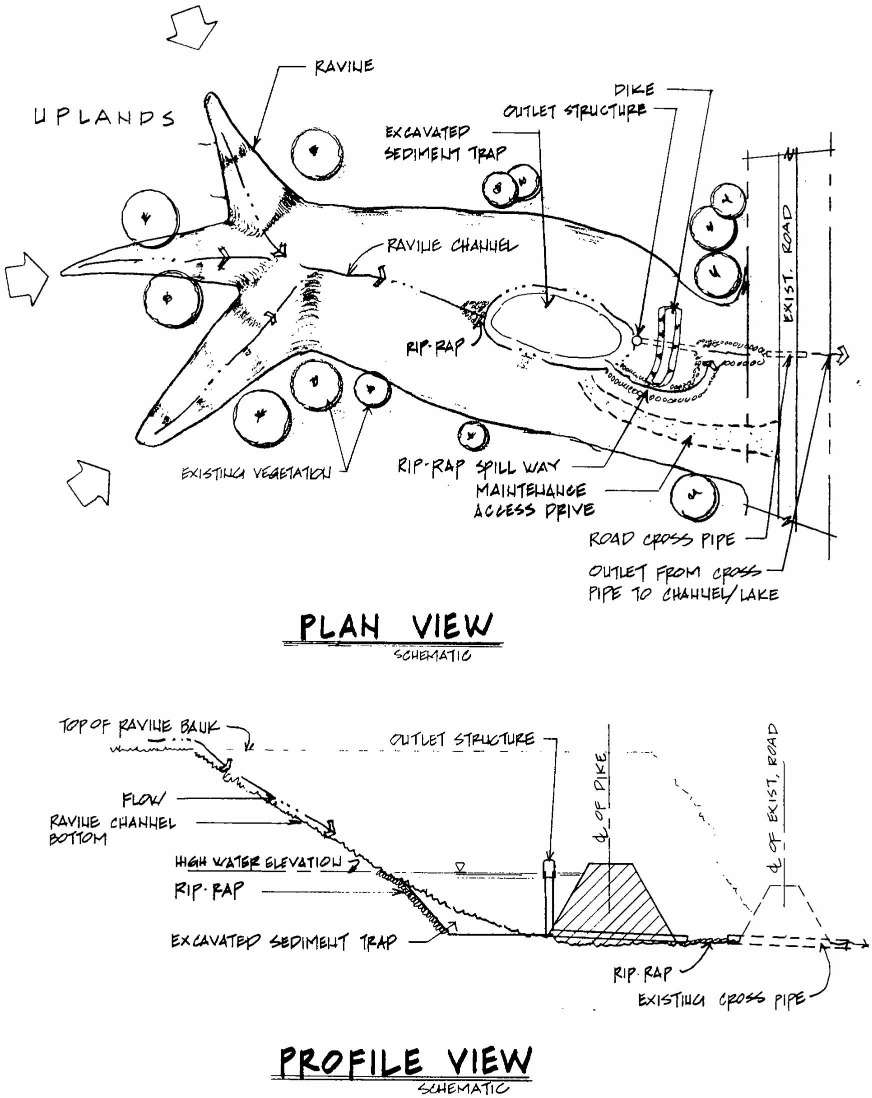


Figure W2. Typical sediment trap construction in a ravine

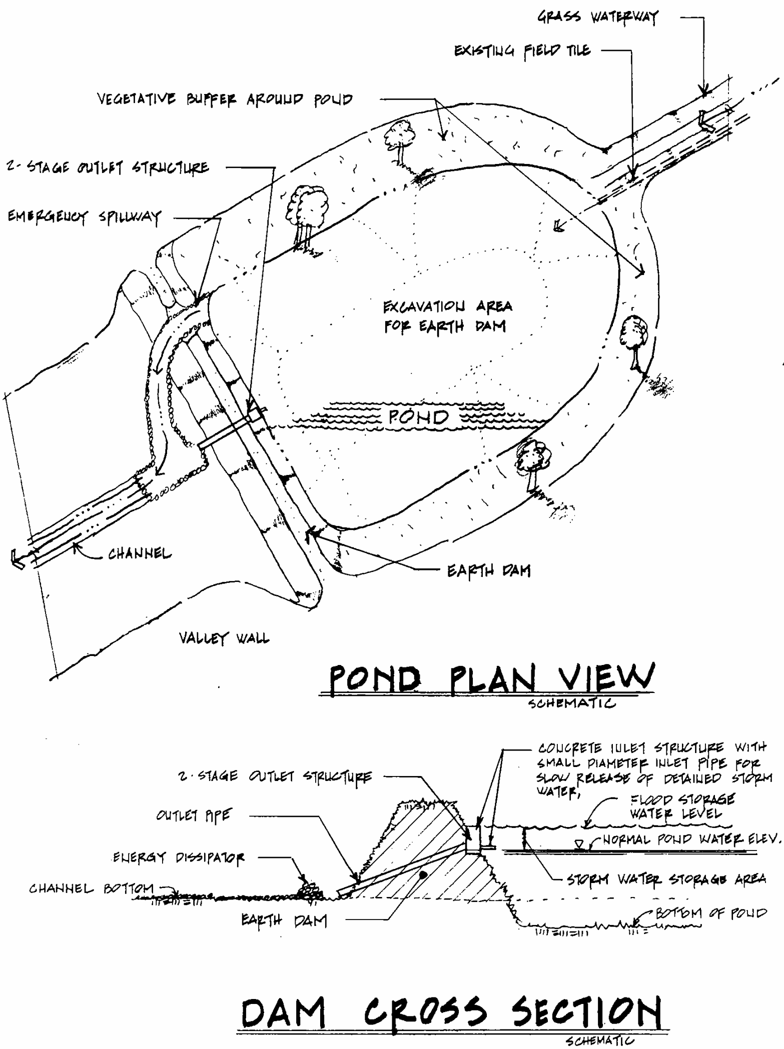


Figure W3. Elements of pond or detention basin construction for stormwater storage

Impoundments should be designed with two-stage outlet structures and sufficient storage capacity above the normal pond water elevation to provide detention for peak runoff flows. In effect these impoundments should be designed to collect and store runoff water and release the runoff into the lower reaches of the drainage channels at low flow rates which do not cause severe channel erosion.

The recommended sites for construction of ponds or detention basins have potential due to location and topography, however the following are a few considerations that must be taken into account prior to design or construction:

- Cooperation of private property owners and availability of a pond site.

- Suitability of soils for embankment construction.

- Embankment location due to environmental concerns.

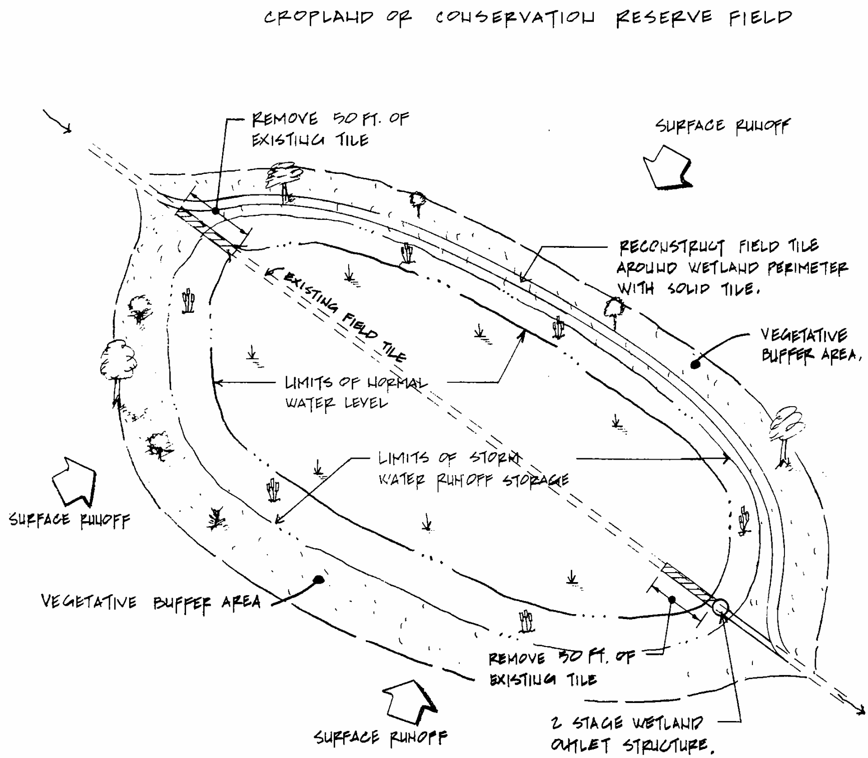
- Sufficient storage capacity to provide adequate detention of storm runoff.

- Maintenance of drainage upstream from the pond.

Site conditions may limit the size and storage capacity of a pond or detention basin. Ideally ponds should be designed with sufficient stormwater storage capacity to accommodate the large runoff flows from infrequent heavy rainfalls, however even minimal detention capacity will aid in sediment removal and reduced frequency of erosive peak runoff discharges in the lower reaches of drainage channels. In larger subwatersheds detention in the form of terraces or restored wetlands could be used in series with a pond.

RESTORED WETLANDS

Wetlands have received much attention during the last several years for their environmental value. Wetlands are noted for their ability to store floodwater, filter sediments and nutrients from runoff waters, recharge groundwater, and provide food and habitat for wildlife. Wetlands are an integral element of a healthy watershed system.



·PLAN VIEW· WETLAND RESTORATION IN DEPRESSION AREA

SCHEMATIC

Figure W4. Typical wetland restoration in an area drained by field tile

Nearly all of the wetland and natural depression areas in the upland subwatersheds have been drained. The elimination of these natural runoff storage areas results in increased peak storm runoff discharges causing erosion in the ravines and channels which flow into the lakes. Restoration or construction of wetlands designed with stormwater detention capacity would assist in reducing peak stormwater runoff flows.

For further information the publication Wetlands and Water Quality by Brian K. Miller is included in the Appendix of the report.

A number of wetlands in the Tri-Lakes Watershed are recommended for restoration on existing tile drains. It is possible to construct or restore a wetland area and maintain tile drainage upstream from the wetland site if the existing field tile is replaced by solid tile and routed around the edge of the wetland. The wetland may then be charged by surface water from the surrounding basin. If there is sufficient tile gradient upstream the flow from the tile may be routed through the wetland. If a maximum high water level must not be exceeded the wetland may be designed with an outlet structure which discharges into the downstream tile.

COST ESTIMATES

A number of factors may affect costs on land restoration or impoundment projects similar to those required for improvements in the Tri-Lakes Watershed. The following are several items which must be considered as direct expenses for completion of a project:

1. Land acquisition or easement rights. (if required)

2. Professional services for site surveying, design, permitting, construction, staking, inspection, and project administration. (if required)

3. Actual project construction and site restoration.

4. Periodic maintenance of the completed project.

If at all possible projects should be kept simple and inexpensive. The Property Owners Association should after preliminary investigations pursue projects which appear to receive the least resistance from affected property owners and permitting agencies. Keep in mind that the goal of these projects is to prevent accelerated eutrophication of the lakes due to sediment and nutrient loading caused by human activities which cause erosion in the watershed. Expensive concessions or amenities requested or required by property owners or permitting agencies may not be cost effective. The Property Owners Association with the assistance of the Whitley County Soil and Water Conservation District should begin investigations to determine which projects could be constructed in an expeditious manner and establish priorities with that information as a factor in the decision making process.

Depending on the size, scope and factors discussed previously the cost of an individual project may vary considerably. The following are estimated cost ranges for recommended construction projects:

1. Sediment traps . . . . $2,000.00 - $10,000.00
2. Restored wetlands . . . . $1,000.00 - $10,000.00
3. Ponds or detention basins . . . $10,000.00 - $100,000.00

PERMITTING AGENCIES

Depending on the location or scope of a project construction permits may or may not be required by regulatory agencies.

The United States Army Corps of Engineers under authority of Section 404 of the Clean Water Act has jurisdiction over the placement of fill in wetlands. If a project requires construction in a wetland contact:

Regulatory Branch
Louisville Corps of Engineers
P.O. Box 59
Louisville, Kentucky 40201
(502) 582-5607

The Indiana Department of Natural Resources (IDNR) has jurisdiction over construction activities in a public freshwater lake or a floodway. The IDNR should be contacted before beginning any work in and around the shoreline of a lake or on ditches draining into the lake as a permit may be required. A permit is required if excavation is proposed in a lake or below lake level in an inflowing channel. A permit is also required if construction of a dam meets any of the following criteria:

1. The drainage area above the dam is more than one square mile.
2. The height of the dam above the stream bed is more than 20 feet.
3. The volume of water impounded by the dam is more than 100 acre-feet.
4. The impoundment affects more than one property owner.

For further information contact:

Indiana Department of Natural Resources
Division of Water
402 West Washington St. Room W 264
Indianapolis, Indiana 46204
(317) 232-4160

The Ott Drain in Little Cedar Lake 2 Subwatershed is the only regulated drain in the Tri-Lakes Watershed. Construction affecting a regulated drain must be permitted by the Whitley County Drainage Board. For further information contact:

Whitley County Drainage Board
Courthouse
Columbia City, Indiana 46725
(219) 248-3108

AGENCIES AND ASSISTANCE PROGRAMS

Technical and/or financial assistance for watershed land and water management projects is available from several public agencies.

INDIANA'S T-by-2000 PROGRAM

The Indiana Department of Natural Resources Division of Soil Conservation administers the T-by-2000 Cropland Erosion Control Cost-Share Program and the Lake Enhancement Program. The Cropland Erosion Control Cost-Share Program is administered by the local Whitley County Soil and Water Conservation District and may provide assistance to landowners in funding expensive structural erosion control measures on farmable land. The Lake Enhancement Program is administered by the IDNR Division of Soil Conservation and may provide funding to eligible lake associations or local governmental units for feasibility studies, design plans, or construction projects in lake watersheds.

Although funding at this time is limited, for further information contact:

Division of Soil Conservation
Indiana Department of Natural Resources
402 West Washington Street, W 265
Indianapolis, IN 46204
Phone (317) 233-3870

or

Whitley County SWCD
1919 East Business 30
Columbia City, IN 46725
Phone (219) 244-6780

WETLAND RESTORATION

The U.S. Fish and Wildlife Service will provide technical services, project management, and funding for the restoration of degraded or drained wetland areas. A representative of the U.S. Fish and Wildlife Service has inspected the proposed restoration sites in the Tri-Lakes Watershed and expressed interest in assisting individual landowners with wetland restoration projects. For further information contact:

U.S. Fish and Wildlife Service
Bloomington Field Office
718 North Walnut Street
Bloomington, IN 47401
Phone (812) 334-4261

CONSERVATION RESERVE PROGRAM AND COST SHARE PRACTICES

Cropland which is highly erodible or meets other conditions is eligible for the long term Conservation Reserve Program (CRP). Land owners bid for rental payments for removal of highly erodible fields from crop production for a period of ten years. An approved vegetative cover must be established on CRP fields for the period of enrollment in the program. The U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service also provides technical assistance and cost sharing for a number of agricultural land management practices. Eligible cost share practices for Whitley County include:

SL-7 Windbreak Restoration or Establishment.
Highest Priority, 11 year minimum lifespan.
This practice is applicable to a farm or ranch in need of protection from serious wind erosion. Cost-sharing for planting trees and shrubs for field and farmstead windbreaks is authorized.

SL-11 Permanent Vegetative Cover on Critical Areas.
Highest Priority, 6 year minimum lifespan.
Cost-sharing is authorized for measures to stabilize a source of sediment for water quality improvement as well as reduction of erosion on such places as gullies, banks, roadsides and similar problem areas. Cost-sharing is also authorized for filter strips, field borders, and open ditch berms with a minimum requirement of 1 rod.

FR-1 Forest Tree Plantation.
Highest Priority, 20 year minimum lifespan.
This practice is designed for the establishment of trees or shrubs for forestry purposes and soil protection.

FR-2 Forest Tree Stand Improvement.
Highest Priority, 20 year minimum lifespan.
This practice is designed to improve and protect desirable trees intended for timber production and to provide soil protection.

FR-3 Site Preparation for Natural Regeneration.
Highest Priority, 11 year minimum lifespan.
The purpose of this practice is to establish a stand of trees for soil protection, forestry purposes, and to preserve and improve the environment.

SL-1 Permanent Vegetative Cover Establishment.
High Priority, 6 year minimum lifespan.
This practice is designed to provide permanent protection to farm or ranch land subject to serious wind or water erosion. This practice requires a soil test.

SL-3 Stripcropping Systems.
High Priority, 6 year minimum lifespan.
The purpose of the practice is to establish a contour or field stripcropping system to protect soil from wind or water erosion and to reduce the pollution of water, air, or land from agricultural non-point sources.

SL-4 Terrace Systems.
High Priority, 11 year minimum lifespan.
This practice is designed to provide maximum control of erosion and sedimentation from cropland.

SL-5 Diversions.
High Priority, 11 year minimum lifespan.
This practice is designed for application where an erosion and sediment problem can be corrected by a single diversion facility as opposed to a system as exemplified by Practice SL-4.

SL-8 Cropland Protective Cover.
High Priority.
The purpose of this practice is to provide needed protection from severe erosion on cropland between crops or pending establishment of enduring protective vegetative cover. the cover must be maintained on the land until after March 1 of the following year.

WP-1 Sediment Retention, Erosion or Water Control Structures.
High Priority, 11 year minimum lifespan.
This practice is designed to control erosion including sediment and chemical runoff from a specific problem area, thereby preventing sedimentation of water.

WP-2 Stream Protection.
High Priority, 11 year minimum lifespan.
The purpose of this practice is to protect streams from sediment or chemicals by installing vegetative filter strips, protective fencing, livestock crossings, or other similar measures.

WP-3 Sod Waterways.
High Priority, 11 year minimum lifespan.
This practice is designed to improve a waterway to safely convey excess water across fields at nonerosive velocities into a watercourse or impoundments.

WP-4 Animal Waste Control Facilities.
High Priority, 11 year minimum lifespan.
This practice is designed to provide facilities for the storage and handling of livestock and poultry waste, so such waste can be recycled into the land in a manner so as to prevent or abate pollution which would otherwise result from such livestock or poultry operations.

WL-1 Permanent Wildlife Habitat.
High Priority, 6 year minimum lifespan.
This practice is designed to provide permanent cover for areas by establishing a permanent stand of trees, shrubs, grasses and legumes, which also provide good permanent wildlife cover and food.

WL-2 Shallow Water Areas for Wildlife.
High Priority, 11 year minimum lifespan.
The purpose of this practice is to develop or restore shallow water areas for wildlife.

SL-2 Permanent Vegetative Cover Improvement.
Medium Priority, 6 year minimum lifespan.
The purpose of this practice is to provide long-range protection to farm or ranch land which is subject to serious wind or water erosion, through improvement of the existing permanent vegetative cover. This practice requires a soil test.

SL-6 Grazing Land Protection.
Medium Priority, 11 year minimum lifespan.
Cost-sharing is authorized for development of springs, seeps, wells, or dugouts, installing pipelines, storage facilities, cisterns, and artificial watersheds.

SL-13 Contour Farming.
Medium Priority, 11 year minimum lifespan.
The purpose of this practice is to demonstrate establishing a contour farming system on nonterraced land to protect soil from wind or water erosion, thus reducing water, air, or land pollution from agricultural nonpoint sources.

WC-1 Water Impoundment Reservoirs.
Medium Priority, 11 year minimum lifespan.
This practice will require erosion control as a purpose along with water conservation. Structures which provide multiple benefits in addition to erosion control and water conservation will be encouraged.

SL-15 No-Till Systems.
Low Priority.
This practice is designed to protect soil from wind and water erosion and to stop or reduce pollution from animal waste, sediment and chemically contaminated runoff.

For further information contact:

Whitley County ASCS
1919 East Business 30
Columbia City, IN 46725
Phone (219) 244-6266

CLASSIFIED WILDLIFE HABITAT ACT

The Indiana Department of Natural Resources Classified Wildlife Habitat Act (CWHA) provides property savings for areas of 15 acres or larger reserved for wildlife habitat. Acreage enrolled in the CWHA is assessed at $1.00 per acre for property tax purposes if enrolled for a 10 year period. Land enrolled in the CWHA may not be used for farming or grazing or contain buildings. The property owner maintains control of the acreage for such purposes of hiking, hunting, or firewood cutting, but is not required to allow public access to the property.

For further information concerning the Classified Wildlife Habitat Act contact:

Division of Fish and Wildlife
Indiana Department of Natural Resources
402 West Washington Street, Room W273
Indianapolis, IN 46204
Phone (317) 232-4080

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APPENDIX A

AGNPS MODEL

TABULAR RESULTS

AGNPS MODEL TABULAR RESULTS

LITTLE CEDAR LAKE 2 SUBWATERSHED

Watershed Summary

Watershed Studied	LCED-2
The area of the watershed is	420 acres
The area of each cell is	10.00 acres
The characteristic storm precipitation is	3.40 inches
The storm energy-intensity value is	66

Values at the Watershed Outlet

Cell number	41 000
Runoff volume	1.5 inches
Peak runoff rate	400 cfs
Total Nitrogen in sediment	1.74 lbs/acre
Total soluble Nitrogen in runoff	3.62 lbs/acre
Soluble Nitrogen concentration in runoff	10.60 ppm
Total Phosphorus in sediment	0.87 lbs/acre
Total soluble Phosphorus in runoff	0.76 lbs/acre
Soluble Phosphorus concentration in runoff	2.22 ppm
Total soluble chemical oxygen demand	42.04 lbs/acre
Soluble chemical oxygen demand concentration in runoff	123 ppm

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.17	0.02	80	6	852.85	0.15	61.1
SILT	0.26	0.00	32	2	497.28	0.08	35.6
SAGG	1.65	0.00	14	1	1316.57	0.22	94.3
LAGG	1.05	0.23	1	0	84.48	0.01	6.1
SAND	0.33	0.08	1	0	22.23	0.00	1.6
TOTAL	3.46	0.26	13	1	2773.42	0.47	198.6

-HYDR- Cell Num	Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstream (cfs)
1	000	10	0.95	0.00	0	0.95	15
2	000	10	1.00	0.00	0	1.00	16
3	000	10	1.85	0.00	0	1.85	27
4	000	10	1.93	0.00	0	1.93	28
5	000	20	0.95	1.93	27	1.44	27
6	000	60	1.00	1.16	49	1.14	50
7	000	10	1.00	0.00	0	1.00	16
8	000	40	1.93	1.64	41	1.72	46
9	000	50	1.70	1.72	45	1.71	50
10	000	120	0.70	1.40	84	1.34	82
11	000	10	0.37	0.00	0	0.37	7
12	000	10	1.70	0.00	0	1.70	25
13	000	20	1.85	1.23	18	1.54	27
14	000	10	1.85	0.00	0	1.85	27
15	000	10	1.17	0.00	0	1.17	18
16	000	130	1.93	1.34	82	1.39	86
17	000	150	1.70	1.31	87	1.34	90
18	000	20	1.77	1.70	24	1.74	31
19	000	10	1.23	0.00	0	1.23	19
20	000	20	1.77	1.85	26	1.81	32
21	000	20	0.70	1.17	18	0.94	18
22	000	10	1.93	0.00	0	1.93	28
23	000	210	1.70	1.46	125	1.47	124
24	000	40	1.70	1.80	46	1.78	51
25	000	10	1.93	0.00	0	1.93	28
26	000	50	1.93	1.37	72	1.49	75
27	000	10	1.93	0.00	0	1.93	28
28	000	20	1.11	1.93	27	1.52	28
29	000	240	1.85	1.47	134	1.49	134
30	000	10	1.93	0.00	0	1.93	28
31	000	70	1.93	1.56	75	1.61	79
32	000	10	1.93	0.00	0	1.93	28
33	000	250	1.93	1.49	223	1.51	224
34	000	80	1.70	1.61	114	1.62	119
35	000	280	1.49	1.54	244	1.54	246
36	000	270	1.93	1.52	140	1.54	142
37	000	90	1.56	1.62	126	1.62	133
38	000	380	0.66	1.56	389	1.53	380
39	000	10	1.93	0.00	0	1.93	28
40	000	10	0.95	0.00	0	0.95	15
41	000	420	0.31	1.53	410	1.51	400
42	000	10	1.85	0.00	0	1.85	27

-SED- Cell Num	Div	Particle Type	Cell Erosion (t/a)	Generated Above (tons)	Generated Within (tons)	Yield (tons)	Deposition (%)
1	000	CLAY	0.01	0.00	0.10	0.22	-54
		SILT	0.02	0.00	0.16	0.21	-23
		SAGG	0.10	0.00	0.98	0.27	73
		LAGG	0.06	0.00	0.61	0.86	-29
		SAND	0.01	0.00	0.12	0.27	-56
		TOTL	0.20	0.00	1.97	1.82	8
2	000	CLAY	0.02	0.00	0.22	0.34	-36
		SILT	0.03	0.00	0.35	0.26	25
		SAGG	0.22	0.00	2.17	0.38	83
		LAGG	0.13	0.00	1.34	0.88	34
		SAND	0.03	0.00	0.26	0.28	-6
		TOTL	0.43	0.00	4.33	2.14	51
3	000	CLAY	0.38	0.00	3.77	4.09	-8
		SILT	0.60	0.00	6.04	2.93	51
		SAGG	3.77	0.00	37.74	5.26	86
		LAGG	2.34	0.00	23.40	2.50	89
		SAND	0.45	0.00	4.53	0.78	83
		TOTL	7.55	0.00	75.48	15.57	79
4	000	CLAY	0.15	0.00	1.52	1.99	-24
		SILT	0.24	0.00	2.43	1.54	37
		SAGG	1.52	0.00	15.19	2.59	83
		LAGG	0.94	0.00	9.42	2.56	73
		SAND	0.18	0.00	1.82	0.80	56
		TOTL	3.04	0.00	30.38	9.48	69
5	000	CLAY	0.00	1.99	0.04	1.74	14
		SILT	0.01	1.54	0.06	0.78	51
		SAGG	0.04	2.59	0.38	0.96	68
		LAGG	0.02	2.56	0.24	3.98	-30
		SAND	0.00	0.80	0.05	1.25	-32
		TOTL	0.08	9.48	0.77	8.71	15
6	000	CLAY	0.02	2.60	0.21	2.67	5
		SILT	0.03	1.49	0.33	1.66	9
		SAGG	0.21	1.96	2.07	2.10	48
		LAGG	0.13	6.61	1.28	6.35	20
		SAND	0.02	2.07	0.25	1.99	14
		TOTL	0.41	14.73	4.13	14.76	22
7	000	CLAY	0.02	0.00	0.19	0.31	-40
		SILT	0.03	0.00	0.30	0.25	18
		SAGG	0.19	0.00	1.86	0.35	81
		LAGG	0.12	0.00	1.16	0.88	23
		SAND	0.02	0.00	0.22	0.28	-19
		TOTL	0.37	0.00	3.73	2.07	44
8	000	CLAY	0.02	13.06	0.23	11.48	14
		SILT	0.04	6.37	0.38	3.12	54
		SAGG	0.23	10.10	2.34	3.81	69
		LAGG	0.15	13.23	1.45	12.74	13
		SAND	0.03	4.14	0.28	3.99	10
		TOTL	0.47	46.90	4.69	35.14	32
9	000	CLAY	0.79	11.48	7.88	17.60	9
		SILT	1.26	3.12	12.61	8.06	49
		SAGG	7.88	3.81	78.83	12.56	85
		LAGG	4.89	12.74	48.88	18.49	70
		SAND	0.95	3.99	9.46	5.77	57
		TOTL	15.77	35.14	157.66	62.49	68

10 000	CLAY	0.25	20.27	2.51	24.09	-5
	SILT	0.40	9.72	4.01	5.96	57
	SAGG	2.51	14.67	25.09	7.18	82
	LAGG	1.56	24.84	15.56	24.17	40
	SAND	0.30	7.76	3.01	7.57	30
	TOTL	5.02	77.26	50.18	68.96	46
11 000	CLAY	0.01	0.00	0.05	0.12	-57
	SILT	0.01	0.00	0.08	0.12	-29
	SAGG	0.05	0.00	0.52	0.15	72
	LAGG	0.03	0.00	0.33	0.50	-34
	SAND	0.01	0.00	0.06	0.16	-59
	TOTL	0.10	0.00	1.05	1.04	1
12 000	CLAY	0.14	0.00	1.39	1.81	-23
	SILT	0.22	0.00	2.23	1.37	39
	SAGG	1.39	0.00	13.94	2.27	84
	LAGG	0.86	0.00	8.64	2.38	72
	SAND	0.17	0.00	1.67	0.75	55
	TOTL	2.79	0.00	27.87	8.57	69
13 000	CLAY	0.54	5.26	5.37	8.97	16
	SILT	0.86	3.30	8.60	3.44	71
	SAGG	5.37	5.73	53.74	4.83	92
	LAGG	3.33	1.97	33.32	10.73	70
	SAND	0.64	0.62	6.45	3.36	53
	TOTL	10.75	16.87	107.49	31.33	75
14 000	CLAY	0.54	0.00	5.37	5.62	-4
	SILT	0.86	0.00	8.60	3.95	54
	SAGG	5.37	0.00	53.74	7.21	87
	LAGG	3.33	0.00	33.32	2.50	92
	SAND	0.64	0.00	6.45	0.78	88
	TOTL	10.75	0.00	107.49	20.06	81
15 000	CLAY	0.18	0.00	1.81	2.08	-13
	SILT	0.18	0.00	1.81	1.02	44
	SAGG	1.45	0.00	14.51	1.93	87
	LAGG	1.81	0.00	18.14	1.92	89
	SAND	5.44	0.00	54.42	0.64	99
	TOTL	9.07	0.00	90.69	7.58	92
16 000	CLAY	0.19	24.09	1.94	24.56	6
	SILT	0.31	5.96	3.10	7.88	13
	SAGG	1.94	7.18	19.37	11.40	57
	LAGG	1.20	24.17	12.01	28.08	22
	SAND	0.23	7.57	2.32	8.79	11
	TOTL	3.87	68.96	38.73	80.70	25
17 000	CLAY	0.16	24.68	1.63	24.91	5
	SILT	0.26	7.99	2.60	8.25	22
	SAGG	1.63	11.54	16.26	11.36	59
	LAGG	1.01	28.57	10.08	29.01	25
	SAND	0.20	8.95	1.95	9.08	17
	TOTL	3.25	81.74	32.52	82.60	28
18 000	CLAY	0.04	1.81	0.37	2.10	4
	SILT	0.06	1.37	0.59	1.84	6
	SAGG	0.37	2.27	3.70	2.30	61
	LAGG	0.23	2.38	2.29	11.38	-59
	SAND	0.04	0.75	0.44	3.57	-67
	TOTL	0.74	8.57	7.40	21.19	-25
19 000	CLAY	0.52	0.00	5.20	5.26	-1
	SILT	0.83	0.00	8.31	3.30	60
	SAGG	5.20	0.00	51.95	5.73	89
	LAGG	3.22	0.00	32.21	1.97	94
	SAND	0.62	0.00	6.23	0.62	90
	TOTL	10.39	0.00	103.91	16.87	84

20 000	CLAY	0.25	5.62	2.47	6.93	14
	SILT	0.40	3.95	3.96	2.60	67
	SAGG	2.47	7.21	24.73	3.35	90
	LAGG	1.53	2.50	15.33	11.78	34
	SAND	0.30	0.78	2.97	3.69	2
	TOTL	4.95	20.06	49.46	28.34	59
21 000	CLAY	0.01	2.08	0.13	1.74	21
	SILT	0.01	1.02	0.13	0.60	47
	SAGG	0.10	1.93	1.01	0.75	75
	LAGG	0.13	1.92	1.26	3.10	2
	SAND	0.38	0.64	3.77	0.93	79
	TOTL	0.63	7.58	6.28	7.12	49
22 000	CLAY	0.15	0.00	1.48	1.96	-25
	SILT	0.24	0.00	2.37	1.52	36
	SAGG	1.48	0.00	14.82	2.54	83
	LAGG	0.92	0.00	9.19	2.56	72
	SAND	0.18	0.00	1.78	0.80	55
	TOTL	2.96	0.00	29.63	9.38	68
23 000	CLAY	0.08	32.52	0.80	31.06	7
	SILT	0.13	13.37	1.28	9.60	34
	SAGG	0.80	18.67	7.98	12.18	54
	LAGG	0.49	44.39	4.95	37.77	23
	SAND	0.10	13.90	0.96	11.83	20
	TOTL	1.60	122.85	15.95	102.44	26
24 000	CLAY	0.08	5.07	0.84	5.65	4
	SILT	0.13	4.04	1.34	3.61	33
	SAGG	0.84	6.17	8.40	4.77	67
	LAGG	0.52	13.94	5.21	12.82	33
	SAND	0.10	4.37	1.01	4.02	25
	TOTL	1.68	33.60	16.79	30.86	39
25 000	CLAY	0.26	0.00	2.56	2.97	-14
	SILT	0.41	0.00	4.10	2.20	46
	SAGG	2.56	0.00	25.63	3.87	85
	LAGG	1.59	0.00	15.89	2.56	84
	SAND	0.31	0.00	3.08	0.80	74
	TOTL	5.13	0.00	51.26	12.41	76
26 000	CLAY	0.17	8.67	1.65	10.24	1
	SILT	0.26	3.20	2.64	4.96	15
	SAGG	1.65	4.10	16.51	12.26	41
	LAGG	1.02	14.87	10.24	0.14	99
	SAND	0.20	4.62	1.98	0.04	99
	TOTL	3.30	35.46	33.02	27.65	60
27 000	CLAY	0.12	0.00	1.19	1.68	-29
	SILT	0.19	0.00	1.91	1.32	31
	SAGG	1.19	0.00	11.92	2.18	82
	LAGG	0.74	0.00	7.39	2.56	65
	SAND	0.14	0.00	1.43	0.80	44
	TOTL	2.38	0.00	23.84	8.53	64
28 000	CLAY	0.01	1.68	0.06	1.52	12
	SILT	0.01	1.32	0.10	0.80	44
	SAGG	0.06	2.18	0.61	0.99	65
	LAGG	0.04	2.56	0.38	4.09	-28
	SAND	0.01	0.80	0.07	1.28	-32
	TOTL	0.12	8.53	1.23	8.69	11
29 000	CLAY	0.11	32.59	1.11	31.61	6
	SILT	0.18	10.40	1.77	10.96	10
	SAGG	1.11	13.17	11.05	14.17	41
	LAGG	0.69	41.86	6.85	43.12	11
	SAND	0.13	13.12	1.33	13.51	6
	TOTL	2.21	111.13	22.11	113.37	15

30 000	CLAY	0.13	0.00	1.32	1.83	-27
	SILT	0.21	0.00	2.12	1.42	33
	SAGG	1.32	0.00	13.24	2.36	82
	LAGG	0.82	0.00	8.21	2.56	69
	SAND	0.16	0.00	1.59	0.80	50
	TOTL	2.65	0.00	26.48	8.97	66
31 000	CLAY	0.02	12.07	0.21	12.18	1
	SILT	0.03	6.39	0.34	5.50	18
	SAGG	0.21	14.61	2.14	6.32	62
	LAGG	0.13	2.70	1.33	0.29	93
	SAND	0.03	0.85	0.26	0.09	92
	TOTL	0.43	36.61	4.28	24.38	40
32 000	CLAY	0.11	0.00	1.06	1.57	-33
	SILT	0.17	0.00	1.69	1.25	26
	SAGG	1.06	0.00	10.58	2.03	81
	LAGG	0.66	0.00	6.56	2.56	61
	SAND	0.13	0.00	1.27	0.80	37
	TOTL	2.12	0.00	21.16	8.21	61
33 000	CLAY	0.08	31.61	0.81	32.33	0
	SILT	0.13	10.96	1.29	11.46	6
	SAGG	0.81	14.17	8.06	17.01	23
	LAGG	0.50	43.12	5.00	0.41	99
	SAND	0.10	13.51	0.97	0.13	99
	TOTL	1.61	113.37	16.12	61.35	53
34 000	CLAY	0.27	12.18	2.70	14.84	0
	SILT	0.43	5.50	4.33	9.14	7
	SAGG	2.70	6.32	27.05	26.21	21
	LAGG	1.68	0.29	16.77	1.75	90
	SAND	0.32	0.09	3.25	0.28	92
	TOTL	5.41	24.38	54.10	52.22	33
35 000	CLAY	0.08	33.16	0.76	33.86	0
	SILT	0.12	12.20	1.22	12.84	4
	SAGG	0.76	15.49	7.60	19.33	16
	LAGG	0.47	93.29	4.71	0.44	100
	SAND	0.09	29.28	0.91	0.14	100
	TOTL	1.52	183.43	15.20	66.61	66
36 000	CLAY	0.05	33.91	0.53	33.16	4
	SILT	0.09	12.71	0.85	12.20	10
	SAGG	0.53	19.04	5.34	15.49	36
	LAGG	0.33	2.97	3.31	93.29	-93
	SAND	0.06	0.93	0.64	29.28	-95
	TOTL	1.07	69.56	10.69	183.43	-56
37 000	CLAY	0.37	14.84	3.73	18.55	0
	SILT	0.60	9.14	5.97	14.75	2
	SAGG	3.73	26.21	37.31	57.37	10
	LAGG	2.31	1.75	23.13	7.40	70
	SAND	0.45	0.28	4.48	1.59	66
	TOTL	7.46	52.22	74.62	99.66	21
38 000	CLAY	0.16	52.42	1.65	54.02	0
	SILT	0.26	27.59	2.63	29.65	2
	SAGG	1.65	76.70	16.46	85.25	8
	LAGG	1.02	7.83	10.21	7.30	60
	SAND	0.20	1.73	1.98	1.77	52
	TOTL	3.29	166.27	32.92	178.00	11
39 000	CLAY	0.04	0.00	0.44	0.98	-55
	SILT	0.07	0.00	0.71	0.85	-16
	SAGG	0.44	0.00	4.44	1.26	72
	LAGG	0.28	0.00	2.75	2.56	7
	SAND	0.05	0.00	0.53	0.80	-34
	TOTL	0.89	0.00	8.88	6.45	27

40 000	CLAY	0.03	0.00	0.28	0.42	-33
	SILT	0.05	0.00	0.45	0.30	33
	SAGG	0.28	0.00	2.84	0.44	85
	LAGG	0.18	0.00	1.76	0.86	51
	SAND	0.03	0.00	0.34	0.27	21
	TOTL	0.57	0.00	5.69	2.29	60
41 000	CLAY	0.09	60.21	0.92	61.08	0
	SILT	0.15	34.83	1.47	35.61	2
	SAGG	0.92	93.95	9.16	94.28	9
	LAGG	0.57	17.75	5.68	6.05	74
	SAND	0.11	5.05	1.10	1.59	74
	TOTL	1.83	211.78	18.32	198.61	14
42 000	CLAY	0.33	0.00	3.28	4.78	-31
	SILT	0.52	0.00	5.25	4.03	23
	SAGG	3.28	0.00	32.81	7.00	79
	LAGG	2.03	0.00	20.34	7.03	65
	SAND	0.39	0.00	3.94	2.20	44
	TOTL	6.56	0.00	65.61	25.04	62

Condensed Soil Loss

Cell Num	Div	RUNOFF Drainage Area (acres)	Volume (in.)	Generated Above (%)	Peak Rate (cfs)	Cell Erosion (t/a)	SEDIMENT Generated Above (tons)	Within (tons)	Yield (tons)	Depo (%)
1	000	10	0.95	0.0	15	0.20	0.00	1.97	1.82	8
2	000	10	1.00	0.0	16	0.43	0.00	4.33	2.14	51
3	000	10	1.85	0.0	27	7.55	0.00	75.48	15.57	79
4	000	10	1.93	0.0	28	3.04	0.00	30.38	9.48	69
5	000	20	0.95	67.1	27	0.08	9.48	0.77	8.71	15
6	000	60	1.00	85.3	50	0.41	14.73	4.13	14.76	22
7	000	10	1.00	0.0	16	0.37	0.00	3.73	2.07	44
8	000	40	1.93	71.9	46	0.47	46.90	4.69	35.14	32
9	000	50	1.70	80.1	50	15.77	35.14	157.66	62.49	68
10	000	120	0.70	95.7	82	5.02	77.26	50.18	68.96	46
11	000	10	0.37	0.0	7	0.10	0.00	1.05	1.04	1
12	000	10	1.70	0.0	25	2.79	0.00	27.87	8.57	69
13	000	20	1.85	39.9	27	10.75	16.87	107.49	31.33	75
14	000	10	1.85	0.0	27	10.75	0.00	107.49	20.06	81
15	000	10	1.17	0.0	18	9.07	0.00	90.69	7.58	92
16	000	130	1.93	89.3	86	3.87	68.96	38.73	80.70	25
17	000	150	1.70	91.5	90	3.25	81.74	32.52	82.60	28
18	000	20	1.77	48.9	31	0.74	8.57	7.40	21.19	-25
19	000	10	1.23	0.0	19	10.39	0.00	103.91	16.87	84
20	000	20	1.77	51.1	32	4.95	20.06	49.46	28.34	59
21	000	20	0.70	62.6	18	0.63	7.58	6.28	7.12	49
22	000	10	1.93	0.0	28	2.96	0.00	29.63	9.38	68
23	000	210	1.70	94.5	124	1.60	122.85	15.95	102.44	26
24	000	40	1.70	76.1	51	1.68	33.60	16.79	30.86	39
25	000	10	1.93	0.0	28	5.13	0.00	51.26	12.41	76
26	000	50	1.93	74.0	75	3.30	35.46	33.02	27.65	60
27	000	10	1.93	0.0	28	2.38	0.00	23.84	8.53	64
28	000	20	1.11	63.4	28	0.12	8.53	1.23	8.69	11
29	000	240	1.85	94.8	134	2.21	111.13	22.11	113.37	15
30	000	10	1.93	0.0	28	2.65	0.00	26.48	8.97	66
31	000	70	1.93	82.9	79	0.43	36.61	4.28	24.38	40
32	000	10	1.93	0.0	28	2.12	0.00	21.16	8.21	61
33	000	250	1.93	94.9	224	1.61	113.37	16.12	61.35	53
34	000	80	1.70	86.9	119	5.41	24.38	54.10	52.22	33
35	000	280	1.49	96.5	246	1.52	183.43	15.20	66.61	66
36	000	270	1.93	95.4	142	1.07	69.56	10.69	183.43	-56
37	000	90	1.56	89.3	133	7.46	52.22	74.62	99.66	21
38	000	380	0.66	98.9	380	3.29	166.27	32.92	178.00	11
39	000	10	1.93	0.0	28	0.89	0.00	8.88	6.45	27
40	000	10	0.95	0.0	15	0.57	0.00	5.69	2.29	60
41	000	420	0.31	99.5	400	1.83	211.78	18.32	198.61	14
42	000	10	1.85	0.0	27	6.56	0.00	65.61	25.04	62

Nutrient Analysis
N I T R O G E N

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	0.86	0.81	0.18	0.18	1
2	000	10	1.62	0.92	0.20	0.20	1
3	000	10	15.94	4.51	3.81	3.81	9
4	000	10	7.70	3.03	7.13	7.13	16
5	000	20	0.40	1.63	0.18	3.66	11
6	000	60	1.56	1.03	0.20	1.35	5
7	000	10	1.44	0.90	0.20	0.20	1
8	000	40	1.73	2.85	0.39	1.86	5
9	000	50	28.73	3.78	2.47	1.98	5
10	000	120	11.50	2.03	4.78	1.90	6
11	000	10	0.52	0.52	0.21	0.21	2
12	000	10	7.18	2.80	3.54	3.54	9
13	000	20	21.15	4.53	2.09	1.62	5
14	000	10	21.15	5.52	3.81	3.81	9
15	000	10	15.69	2.16	0.68	0.68	3
16	000	130	9.35	2.16	6.66	2.26	7
17	000	150	8.13	1.96	1.94	2.11	7
18	000	20	2.49	3.31	3.99	3.76	10
19	000	10	20.58	4.81	1.15	1.15	4
20	000	20	11.37	4.18	2.78	3.29	8
21	000	20	1.85	1.18	0.13	0.40	2
22	000	10	7.54	3.01	6.66	6.66	15
23	000	210	4.60	1.78	3.54	2.55	8
24	000	40	4.79	2.57	1.94	2.95	7
25	000	10	11.70	3.76	2.35	2.35	5
26	000	50	8.23	1.97	8.23	3.13	9
27	000	10	6.34	2.79	8.23	8.23	19
28	000	20	0.59	1.62	0.22	4.22	12
29	000	240	5.97	1.74	1.40	2.64	8
30	000	10	6.90	2.90	9.80	9.80	22
31	000	70	1.60	1.36	9.80	5.03	14
32	000	10	5.76	2.70	9.80	9.80	22
33	000	250	4.64	1.03	9.80	2.93	9
34	000	80	12.21	2.25	1.94	4.64	13
35	000	280	4.42	1.00	1.62	3.37	10
36	000	270	3.34	2.32	9.80	3.44	10
37	000	90	15.79	3.43	1.31	4.27	12
38	000	380	8.21	1.72	0.28	3.51	10
39	000	10	2.88	2.23	9.80	9.80	22
40	000	10	2.01	0.97	0.18	0.18	1
41	000	420	5.14	1.74	0.06	3.62	11
42	000	10	14.25	6.59	8.63	8.63	21

Nutrient Analysis
P H O S P H O R U S

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	0.43	0.40	0.01	0.01	0
2	000	10	0.81	0.46	0.01	0.01	0
3	000	10	7.97	2.25	0.79	0.79	2
4	000	10	3.85	1.52	1.53	1.53	4
5	000	20	0.20	0.81	0.01	0.77	2
6	000	60	0.78	0.52	0.01	0.26	1
7	000	10	0.72	0.45	0.01	0.01	0
8	000	40	0.86	1.43	0.02	0.36	1
9	000	50	14.37	1.89	0.49	0.38	1
10	000	120	5.75	1.02	1.00	0.38	1
11	000	10	0.26	0.26	0.01	0.01	0
12	000	10	3.59	1.40	0.73	0.73	2
13	000	20	10.57	2.27	0.40	0.31	1
14	000	10	10.57	2.76	0.79	0.79	2
15	000	10	7.85	1.08	0.11	0.11	0
16	000	130	4.67	1.08	1.43	0.46	1
17	000	150	4.06	0.98	0.37	0.42	1
18	000	20	1.24	1.66	0.83	0.78	2
19	000	10	10.29	2.40	0.21	0.21	1
20	000	20	5.68	2.09	0.56	0.67	2
21	000	20	0.93	0.59	0.01	0.06	0
22	000	10	3.77	1.50	1.43	1.43	3
23	000	210	2.30	0.89	0.73	0.52	2
24	000	40	2.39	1.29	0.37	0.60	1
25	000	10	5.85	1.88	0.46	0.46	1
26	000	50	4.11	0.98	1.78	0.65	2
27	000	10	3.17	1.39	1.78	1.78	4
28	000	20	0.30	0.81	0.01	0.90	3
29	000	240	2.98	0.87	0.25	0.54	2
30	000	10	3.45	1.45	2.13	2.13	5
31	000	70	0.80	0.68	2.13	1.07	3
32	000	10	2.88	1.35	2.13	2.13	5
33	000	250	2.32	0.51	2.13	0.60	2
34	000	80	6.11	1.12	0.37	0.98	3
35	000	280	2.21	0.50	0.31	0.70	2
36	000	270	1.67	1.16	2.13	0.71	2
37	000	90	7.90	1.72	0.24	0.90	2
38	000	380	4.10	0.86	0.04	0.73	2
39	000	10	1.44	1.11	2.13	2.13	5
40	000	10	1.01	0.49	0.01	0.01	0
41	000	420	2.57	0.87	0.00	0.76	2
42	000	10	7.12	3.30	1.86	1.86	4

Nutrient Analysis
Chemical Oxygen Demand

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10			14.00	13.94	65
2	000	10			14.00	13.83	61
3	000	10			52.00	52.41	125
4	000	10			69.00	68.62	157
5	000	20			14.00	41.28	127
6	000	60			14.00	22.92	89
7	000	10			14.00	13.60	60
8	000	40			28.00	40.66	105
9	000	50			31.00	38.69	100
10	000	120			64.00	32.89	108
11	000	10			15.00	15.07	181
12	000	10			31.00	30.81	80
13	000	20			52.00	41.13	118
14	000	10			52.00	52.41	125
15	000	10			21.00	21.23	80
16	000	130			74.00	36.08	115
17	000	150			31.00	34.33	113
18	000	20			32.00	31.49	80
19	000	10			30.00	29.85	107
20	000	20			43.00	47.71	116
21	000	20			14.00	17.43	82
22	000	10			74.00	74.30	170
23	000	210			31.00	37.53	113
24	000	40			31.00	42.02	104
25	000	10			74.00	74.30	170
26	000	50			74.00	40.92	122
27	000	10			74.00	74.30	170
28	000	20			14.00	44.34	129
29	000	240			31.00	37.84	112
30	000	10			74.00	74.30	170
31	000	70			74.00	50.46	138
32	000	10			73.00	72.55	166
33	000	250			77.00	39.42	116
34	000	80			41.00	49.25	134
35	000	280			36.00	41.75	120
36	000	270			74.00	41.94	120
37	000	90			27.00	46.80	128
38	000	380			16.00	42.26	122
39	000	10			74.00	74.30	170
40	000	10			14.00	13.94	65
41	000	420			5.00	42.04	123
42	000	10			67.00	67.09	160

AGNPS MODEL TABULAR RESULTS

ROUND LAKE 1 SUBWATERSHED

Watershed Summary

Watershed Studied	ROUND-1
The area of the watershed is	150 acres
The area of each cell is	10.00 acres
The characteristic storm precipitation is	3.40 inches
The storm energy-intensity value is	66

Values at the Watershed Outlet

Cell number	15 000
Runoff volume	1.5 inches
Peak runoff rate	148 cfs
Total Nitrogen in sediment	4.70 lbs/acre
Total soluble Nitrogen in runoff	1.91 lbs/acre
Soluble Nitrogen concentration in runoff	5.55 ppm
Total Phosphorus in sediment	2.35 lbs/acre
Total soluble Phosphorus in runoff	0.37 lbs/acre
Soluble Phosphorus concentration in runoff	1.07 ppm
Total soluble chemical oxygen demand	42.03 lbs/acre
Soluble chemical oxygen demand concentration in runoff	122 ppm

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.22	0.00	114	3	1442.51	0.25	37.2
SILT	0.35	0.00	87	2	1747.45	0.30	45.0
SAGG	2.16	0.00	50	1	6289.26	1.08	162.1
LAGG	1.34	0.00	1	0	52.13	0.01	1.3
SAND	0.26	0.00	1	0	13.61	0.00	0.4
TOTAL	4.32	0.00	38	1	9544.96	1.64	246.0

-SED- Cell Num	Div	Particle Type	Cell Erosion (t/a)	Generated Above (tons)	Generated Within (tons)	Yield (tons)	Deposition (%)
1	000	CLAY	0.01	0.00	0.08	0.09	-15
		SILT	0.01	0.00	0.12	0.13	-6
		SAGG	0.08	0.00	0.76	0.64	16
		LAGG	0.05	0.00	0.47	0.11	76
		SAND	0.01	0.00	0.09	0.03	69
		TOTL	0.15	0.00	1.52	1.00	34
2	000	CLAY	0.01	0.00	0.08	0.09	-15
		SILT	0.01	0.00	0.12	0.13	-6
		SAGG	0.08	0.00	0.76	0.64	16
		LAGG	0.05	0.00	0.47	0.11	76
		SAND	0.01	0.00	0.09	0.03	69
		TOTL	0.15	0.00	1.52	0.99	34
3	000	CLAY	0.37	0.00	3.74	3.75	0
		SILT	0.60	0.00	5.98	5.77	4
		SAGG	3.74	0.00	37.37	31.44	16
		LAGG	2.32	0.00	23.17	2.60	89
		SAND	0.45	0.00	4.48	0.39	91
		TOTL	7.47	0.00	74.74	43.94	41
4	000	CLAY	0.16	0.18	1.62	1.80	0
		SILT	0.26	0.26	2.60	2.65	7
		SAGG	1.62	1.27	16.22	12.65	28
		LAGG	1.01	0.23	10.06	1.24	88
		SAND	0.19	0.06	1.95	0.30	85
		TOTL	3.24	1.99	32.45	18.64	46
5	000	CLAY	0.29	0.00	2.88	2.89	0
		SILT	0.46	0.00	4.60	4.44	4
		SAGG	2.88	0.00	28.78	24.08	16
		LAGG	1.78	0.00	17.84	1.96	89
		SAND	0.35	0.00	3.45	0.29	91
		TOTL	5.76	0.00	57.55	33.66	42
6	000	CLAY	0.18	0.00	1.77	1.80	-1
		SILT	0.28	0.00	2.84	2.74	3
		SAGG	1.77	0.00	17.73	14.73	17
		LAGG	1.10	0.00	10.99	1.22	89
		SAND	0.21	0.00	2.13	0.19	91
		TOTL	3.55	0.00	35.46	20.69	42
7	000	CLAY	0.17	15.71	1.71	20.15	-14
		SILT	0.27	24.08	2.73	22.75	15
		SAGG	1.71	130.10	17.07	87.39	41
		LAGG	1.06	11.42	10.59	0.92	96
		SAND	0.20	1.82	2.05	0.29	93
		TOTL	3.41	183.12	34.15	131.50	39
8	000	CLAY	0.55	0.00	5.46	5.48	0
		SILT	0.87	0.00	8.74	8.48	3
		SAGG	5.46	0.00	54.64	47.19	14
		LAGG	3.39	0.00	33.88	4.39	87
		SAND	0.66	0.00	6.56	0.65	90
		TOTL	10.93	0.00	109.28	66.19	39
9	000	CLAY	0.21	0.00	2.09	2.12	-1
		SILT	0.33	0.00	3.35	3.24	3
		SAGG	2.09	0.00	20.93	17.39	17
		LAGG	1.30	0.00	12.98	1.42	89
		SAND	0.25	0.00	2.51	0.22	91
		TOTL	4.19	0.00	41.87	24.39	42

10 000	CLAY	0.28	23.78	2.80	26.54	0
	SILT	0.45	28.32	4.48	31.52	4
	SAGG	2.80	117.78	28.00	121.38	17
	LAGG	1.74	3.55	17.36	3.59	83
	SAND	0.34	0.69	3.36	0.60	85
	TOTL	5.60	174.12	56.00	183.61	20
11 000	CLAY	0.62	26.54	6.19	32.66	0
	SILT	0.99	31.52	9.90	39.54	5
	SAGG	6.19	121.38	61.85	149.07	19
	LAGG	3.83	3.59	38.35	6.77	84
	SAND	0.74	0.60	7.42	1.13	86
	TOTL	12.37	183.61	123.70	229.18	25
12 000	CLAY	0.20	32.66	2.04	36.71	-5
	SILT	0.33	39.54	3.26	45.22	-5
	SAGG	2.04	149.07	20.39	174.61	-3
	LAGG	1.26	6.77	12.64	7.53	61
	SAND	0.24	1.13	2.45	0.29	92
	TOTL	4.08	229.18	40.78	264.37	2
13 000	CLAY	0.02	0.00	0.16	0.19	-15
	SILT	0.03	0.00	0.26	0.28	-7
	SAGG	0.16	0.00	1.64	1.46	11
	LAGG	0.10	0.00	1.01	0.27	73
	SAND	0.02	0.00	0.20	0.06	68
	TOTL	0.33	0.00	3.27	2.27	31
14 000	CLAY	0.15	0.00	1.51	1.51	0
	SILT	0.24	0.00	2.41	2.34	3
	SAGG	1.51	0.00	15.07	13.00	14
	LAGG	0.93	0.00	9.34	1.21	87
	SAND	0.18	0.00	1.81	0.18	90
	TOTL	3.01	0.00	30.13	18.24	39
15 000	CLAY	0.03	36.90	0.31	37.18	0
	SILT	0.05	45.51	0.49	45.04	2
	SAGG	0.31	176.07	3.08	162.11	10
	LAGG	0.19	7.80	1.91	1.34	86
	SAND	0.04	0.36	0.37	0.35	52
	TOTL	0.62	266.63	6.16	246.02	10

Condensed Soil Loss

Cell Num	Div	Drainage Area (acres)	RUNOFF Volume (in.)	Generated Above (%)	Peak Rate (cfs)	Cell Erosion (t/a)	SEDIMENT Generated Above (tons)	Generated Within (tons)	Yield (tons)	Depo (%)
1	000	10	1.63	0.0	36	0.15	0.00	1.52	1.00	34
2	000	10	1.63	0.0	36	0.15	0.00	1.52	0.99	34
3	000	10	1.70	0.0	39	7.47	0.00	74.74	43.94	41
4	000	30	1.70	65.7	60	3.24	1.99	32.45	18.64	46
5	000	10	1.70	0.0	38	5.76	0.00	57.55	33.66	42
6	000	10	1.93	0.0	40	3.55	0.00	35.46	20.69	42
7	000	80	0.45	96.5	116	3.41	183.12	34.15	131.50	39
8	000	10	1.93	0.0	46	10.93	0.00	109.28	66.19	39
9	000	10	1.93	0.0	40	4.19	0.00	41.87	24.39	42
10	000	110	1.85	89.6	133	5.60	174.12	56.00	183.61	20
11	000	120	2.26	88.7	179	12.37	183.61	123.70	229.18	25
12	000	130	0.29	98.6	143	4.08	229.18	40.78	264.37	2
13	000	10	1.29	0.0	34	0.33	0.00	3.27	2.27	31
14	000	10	1.36	0.0	30	3.01	0.00	30.13	18.24	39
15	000	150	1.11	95.1	148	0.62	266.63	6.16	246.02	10

Nutrient Analysis

N I T R O G E N

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	0.70	0.50	1.73	1.73	5
2	000	10	0.70	0.50	1.73	1.73	5
3	000	10	15.81	10.34	2.47	2.47	6
4	000	30	8.11	2.16	2.47	1.98	5
5	000	10	12.83	8.35	2.47	2.47	6
6	000	10	8.71	5.66	3.52	3.52	8
7	000	80	8.45	4.71	3.52	2.68	7
8	000	10	21.43	14.35	3.52	3.52	8
9	000	10	9.95	6.46	1.96	1.96	4
10	000	110	12.55	4.77	3.47	2.49	7
11	000	120	23.67	5.31	0.46	2.32	6
12	000	130	9.74	5.58	0.25	2.16	6
13	000	10	1.29	0.97	0.25	0.25	1
14	000	10	7.65	5.12	0.53	0.53	2
15	000	150	2.15	4.70	0.22	1.91	6

Nutrient Analysis
P H O S P H O R U S

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	0.35	0.25	0.33	0.33	1
2	000	10	0.35	0.25	0.33	0.33	1
3	000	10	7.91	5.17	0.49	0.49	1
4	000	30	4.06	1.08	0.49	0.38	1
5	000	10	6.42	4.18	0.49	0.49	1
6	000	10	4.36	2.83	0.72	0.72	2
7	000	80	4.23	2.35	0.72	0.54	2
8	000	10	10.72	7.17	0.72	0.72	2
9	000	10	4.97	3.23	0.37	0.37	1
10	000	110	6.28	2.38	0.71	0.50	1
11	000	120	11.83	2.65	0.03	0.46	1
12	000	130	4.87	2.79	0.01	0.42	1
13	000	10	0.65	0.48	0.01	0.01	0
14	000	10	3.82	2.56	0.07	0.07	0
15	000	150	1.07	2.35	0.01	0.37	1

Nutrient Analysis
Chemical Oxygen Demand

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10			10.00	9.59	26
2	000	10			8.00	8.48	23
3	000	10			31.00	30.81	80
4	000	30			31.00	16.29	44
5	000	10			31.00	30.81	80
6	000	10			74.00	74.30	170
7	000	80			74.00	41.46	116
8	000	10			73.00	72.55	166
9	000	10			74.00	74.30	170
10	000	110			69.00	45.77	125
11	000	120			66.00	47.42	125
12	000	130			22.00	45.49	128
13	000	10			20.00	19.63	67
14	000	10			28.00	28.27	92
15	000	150			19.00	42.03	122

AGNPS MODEL TABULAR RESULTS

SHRINER LAKE 2 SUBWATERSHED

Watershed Summary

Watershed Studied	SHRINER-2
The area of the watershed is	190 acres
The area of each cell is	10.00 acres
The characteristic storm precipitation is	3.40 inches
The storm energy-intensity value is	66

Values at the Watershed Outlet

Cell number	11 000
Runoff volume	1.4 inches
Peak runoff rate	214 cfs
Total Nitrogen in sediment	1.27 lbs/acre
Total soluble Nitrogen in runoff	1.08 lbs/acre
Soluble Nitrogen concentration in runoff	3.51 ppm
Total Phosphorus in sediment	0.63 lbs/acre
Total soluble Phosphorus in runoff	0.20 lbs/acre
Soluble Phosphorus concentration in runoff	0.64 ppm
Total soluble chemical oxygen demand	30.15 lbs/acre
Soluble chemical oxygen demand concentration in runoff	98 ppm

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.08	0.01	94	6	569.31	0.09	16.7
SILT	0.13	0.00	45	2	383.71	0.06	11.3
SAGG	0.80	0.00	20	1	1035.87	0.16	30.4
LAGG	0.50	0.02	2	0	60.11	0.01	1.8
SAND	0.10	0.01	2	0	11.37	0.00	0.3
TOTAL	1.61	0.02	20	1	2060.37	0.32	60.5

-HYDR- Cell Num	Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstream (cfs)
1	000	10	1.17	0.00	0	1.17	18
2	000	10	1.17	0.00	0	1.17	18
3	000	10	1.70	0.00	0	1.70	25
4	000	10	1.70	0.00	0	1.70	25
5	000	10	1.70	0.00	0	1.70	25
6	000	10	1.93	0.00	0	1.93	28
7	000	60	1.93	1.25	80	1.37	66
8	000	70	1.70	1.37	97	1.41	96
9	000	130	1.70	1.37	164	1.40	159
10	000	150	1.70	1.42	172	1.44	174
11	000	190	1.23	1.37	217	1.36	214
12	000	10	1.00	0.00	0	1.00	16
13	000	10	1.00	0.00	0	1.00	16
14	000	20	1.00	1.00	15	1.00	21
15	000	30	1.17	1.00	21	1.06	27
16	000	170	1.06	1.41	201	1.39	199
17	000	180	1.06	1.39	219	1.37	217
18	000	10	1.00	0.00	0	1.00	16
19	000	10	1.00	0.00	0	1.00	16

-SED- Cell Num	Div	Particle Type	Cell Erosion (t/a)	Generated Above (tons)	Generated Within (tons)	Yield (tons)	Deposition (%)
1	000	CLAY	0.19	0.00	1.94	1.95	-1
		SILT	0.31	0.00	3.10	1.12	64
		SAGG	1.94	0.00	19.40	1.86	90
		LAGG	1.20	0.00	12.03	0.97	92
		SAND	0.23	0.00	2.33	0.30	87
		TOTL	3.88	0.00	38.80	6.21	84
2	000	CLAY	0.04	0.00	0.40	0.54	-26
		SILT	0.06	0.00	0.64	0.38	41
		SAGG	0.40	0.00	4.02	0.58	86
		LAGG	0.25	0.00	2.49	0.97	61
		SAND	0.05	0.00	0.48	0.30	37
		TOTL	0.80	0.00	8.04	2.77	65
3	000	CLAY	0.04	0.00	0.35	0.79	-56
		SILT	0.06	0.00	0.56	0.70	-20
		SAGG	0.35	0.00	3.51	1.03	71
		LAGG	0.22	0.00	2.18	2.38	-9
		SAND	0.04	0.00	0.42	0.75	-44
		TOTL	0.70	0.00	7.02	5.65	20
4	000	CLAY	0.10	0.00	0.99	1.41	-30
		SILT	0.16	0.00	1.59	1.11	30
		SAGG	0.99	0.00	9.92	1.79	82
		LAGG	0.62	0.00	6.15	2.38	61
		SAND	0.12	0.00	1.19	0.75	37
		TOTL	1.98	0.00	19.84	7.43	63
5	000	CLAY	0.11	0.00	1.07	1.48	-28
		SILT	0.17	0.00	1.71	1.15	33
		SAGG	1.07	0.00	10.67	1.87	82
		LAGG	0.66	0.00	6.61	2.38	64
		SAND	0.13	0.00	1.28	0.75	42
		TOTL	2.13	0.00	21.33	7.63	64
6	000	CLAY	0.36	0.00	3.57	3.63	-2
		SILT	0.57	0.00	5.72	2.35	59
		SAGG	3.57	0.00	35.72	4.16	88
		LAGG	2.21	0.00	22.15	1.29	94
		SAND	0.43	0.00	4.29	0.41	91
		TOTL	7.14	0.00	71.44	11.84	83
7	000	CLAY	0.15	6.68	1.45	7.23	11
		SILT	0.23	4.33	2.32	2.07	69
		SAGG	1.45	7.24	14.52	2.79	87
		LAGG	0.90	5.00	9.00	7.33	48
		SAND	0.17	1.57	1.74	2.30	31
		TOTL	2.90	24.82	29.05	21.73	60
8	000	CLAY	0.03	7.23	0.33	7.53	0
		SILT	0.05	2.07	0.53	2.36	9
		SAGG	0.33	2.79	3.32	4.26	30
		LAGG	0.21	7.33	2.06	0.38	96
		SAND	0.04	2.30	0.40	0.12	96
		TOTL	0.66	21.73	6.64	14.65	48
9	000	CLAY	0.09	10.86	0.92	11.75	0
		SILT	0.15	5.18	1.47	6.23	6
		SAGG	0.92	8.36	9.18	13.65	22
		LAGG	0.57	9.04	5.69	0.74	95
		SAND	0.11	2.83	1.10	0.16	96
		TOTL	1.84	36.28	18.36	32.52	40

10 000	CLAY	0.09	13.23	0.92	14.12	0
	SILT	0.15	7.38	1.47	8.45	4
	SAGG	0.92	15.52	9.18	20.37	18
	LAGG	0.57	3.12	5.69	1.39	84
	SAND	0.11	0.90	1.10	0.28	86
	TOTL	1.84	40.15	18.36	44.62	24
11 000	CLAY	0.13	15.45	1.30	16.71	0
	SILT	0.21	9.70	2.07	11.27	4
	SAGG	1.30	23.75	12.96	30.41	17
	LAGG	0.80	1.54	8.04	1.76	82
	SAND	0.16	0.30	1.56	0.33	82
	TOTL	2.59	50.74	25.92	60.49	21
12 000	CLAY	0.02	0.00	0.22	0.34	-36
	SILT	0.03	0.00	0.35	0.26	25
	SAGG	0.22	0.00	2.17	0.38	83
	LAGG	0.13	0.00	1.34	0.88	34
	SAND	0.03	0.00	0.26	0.28	-6
	TOTL	0.43	0.00	4.33	2.14	51
13 000	CLAY	0.01	0.00	0.09	0.22	-57
	SILT	0.02	0.00	0.15	0.21	-29
	SAGG	0.09	0.00	0.94	0.27	72
	LAGG	0.06	0.00	0.59	0.88	-34
	SAND	0.01	0.00	0.11	0.28	-59
	TOTL	0.19	0.00	1.89	1.86	1
14 000	CLAY	0.01	0.25	0.13	0.70	-46
	SILT	0.02	0.22	0.20	0.84	-50
	SAGG	0.13	0.31	1.27	1.19	24
	LAGG	0.08	0.88	0.79	4.11	-59
	SAND	0.02	0.28	0.15	1.29	-67
	TOTL	0.25	1.94	2.54	8.12	-45
15 000	CLAY	0.02	0.70	0.19	1.12	-21
	SILT	0.03	0.84	0.31	1.02	11
	SAGG	0.19	1.19	1.91	1.29	59
	LAGG	0.12	4.11	1.19	3.90	26
	SAND	0.02	1.29	0.23	1.22	19
	TOTL	0.38	8.12	3.83	8.55	28
16 000	CLAY	0.02	14.46	0.22	14.65	0
	SILT	0.03	8.71	0.35	8.71	4
	SAGG	0.22	20.75	2.18	19.08	17
	LAGG	0.13	2.28	1.35	0.71	80
	SAND	0.03	0.56	0.26	0.18	78
	TOTL	0.44	46.76	4.35	43.34	15
17 000	CLAY	0.08	14.65	0.82	15.45	0
	SILT	0.13	8.71	1.31	9.70	3
	SAGG	0.82	19.08	8.16	23.75	13
	LAGG	0.51	0.71	5.06	1.54	73
	SAND	0.10	0.18	0.98	0.30	74
	TOTL	1.63	43.34	16.31	50.74	15
18 000	CLAY	0.01	0.00	0.13	0.25	-47
	SILT	0.02	0.00	0.21	0.22	-1
	SAGG	0.13	0.00	1.34	0.31	77
	LAGG	0.08	0.00	0.83	0.88	-6
	SAND	0.02	0.00	0.16	0.28	-42
	TOTL	0.27	0.00	2.68	1.94	28
19 000	CLAY	0.02	0.00	0.22	0.34	-36
	SILT	0.03	0.00	0.35	0.26	25
	SAGG	0.22	0.00	2.17	0.38	83
	LAGG	0.13	0.00	1.34	0.88	34
	SAND	0.03	0.00	0.26	0.28	-6
	TOTL	0.43	0.00	4.33	2.14	51

Condensed Soil Loss

Cell Num	Div	Drainage Area (acres)	RUNOFF Volume (in.)	Generated Above (%)	Peak Rate (cfs)	Cell Erosion (t/a)	SEDIMENT Generated Above (tons)	Generated Within (tons)	Yield (tons)	Depo (%)
1	000	10	1.17	0.0	18	3.88	0.00	38.80	6.21	84
2	000	10	1.17	0.0	18	0.80	0.00	8.04	2.77	65
3	000	10	1.70	0.0	25	0.70	0.00	7.02	5.65	20
4	000	10	1.70	0.0	25	1.98	0.00	19.84	7.43	63
5	000	10	1.70	0.0	25	2.13	0.00	21.33	7.63	64
6	000	10	1.93	0.0	28	7.14	0.00	71.44	11.84	83
7	000	60	1.93	76.5	66	2.90	24.82	29.05	21.73	60
8	000	70	1.70	82.8	96	0.66	21.73	6.64	14.65	48
9	000	130	1.70	90.6	159	1.84	36.28	18.36	32.52	40
10	000	150	1.70	92.1	174	1.84	40.15	18.36	44.62	24
11	000	190	1.23	95.2	214	2.59	50.74	25.92	60.49	21
12	000	10	1.00	0.0	16	0.43	0.00	4.33	2.14	51
13	000	10	1.00	0.0	16	0.19	0.00	1.89	1.86	1
14	000	20	1.00	50.0	21	0.25	1.94	2.54	8.12	-45
15	000	30	1.17	63.1	27	0.38	8.12	3.83	8.55	28
16	000	170	1.06	95.5	199	0.44	46.76	4.35	43.34	15
17	000	180	1.06	95.7	217	1.63	43.34	16.31	50.74	15
18	000	10	1.00	0.0	16	0.27	0.00	2.68	1.94	28
19	000	10	1.00	0.0	16	0.43	0.00	4.33	2.14	51

Nutrient Analysis
N I T R O G E N

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	9.36	2.16	0.63	0.63	2
2	000	10	2.66	1.13	0.23	0.23	1
3	000	10	2.38	2.00	1.94	1.94	5
4	000	10	5.47	2.49	1.94	1.94	5
5	000	10	5.80	2.55	1.94	1.94	5
6	000	10	15.25	3.62	4.31	4.31	10
7	000	60	7.42	1.40	2.35	1.32	4
8	000	70	2.28	0.91	1.54	1.35	4
9	000	130	5.14	1.04	1.94	1.22	4
10	000	150	5.14	1.20	1.94	1.32	4
11	000	190	6.78	1.27	0.24	1.08	4
12	000	10	1.62	0.92	0.20	0.20	1
13	000	10	0.83	0.82	0.20	0.20	1
14	000	20	1.06	1.54	0.20	0.20	1
15	000	30	1.47	1.16	0.23	0.21	1
16	000	170	1.63	1.06	0.21	1.19	4
17	000	180	4.68	1.15	0.21	1.13	4
18	000	10	1.10	0.85	0.20	0.20	1
19	000	10	1.62	0.92	0.20	0.20	1

Nutrient Analysis

P H O S P H O R U S

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	10	4.68	1.08	0.10	0.10	0
2	000	10	1.33	0.57	0.01	0.01	0
3	000	10	1.19	1.00	0.37	0.37	1
4	000	10	2.74	1.25	0.37	0.37	1
5	000	10	2.90	1.27	0.37	0.37	1
6	000	10	7.63	1.81	0.90	0.90	2
7	000	60	3.71	0.70	0.46	0.25	1
8	000	70	1.14	0.45	0.28	0.25	1
9	000	130	2.57	0.52	0.37	0.23	1
10	000	150	2.57	0.60	0.37	0.25	1
11	000	190	3.39	0.63	0.01	0.20	1
12	000	10	0.81	0.46	0.01	0.01	0
13	000	10	0.42	0.41	0.01	0.01	0
14	000	20	0.53	0.77	0.01	0.01	0
15	000	30	0.73	0.58	0.01	0.01	0
16	000	170	0.81	0.53	0.01	0.22	1
17	000	180	2.34	0.57	0.01	0.21	1
18	000	10	0.55	0.43	0.01	0.01	0
19	000	10	0.81	0.46	0.01	0.01	0

Nutrient Analysis
Chemical Oxygen Demand

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Water Soluble Conc (ppm)
1	000	10			18.00	17.51	66
2	000	10			18.00	17.51	66
3	000	10			31.00	30.81	80
4	000	10			31.00	30.81	80
5	000	10			31.00	30.81	80
6	000	10			74.00	74.30	170
7	000	60			74.00	35.14	113
8	000	70			31.00	34.52	108
9	000	130			65.00	31.80	100
10	000	150			65.00	33.98	104
11	000	190			20.00	30.15	98
12	000	10			14.00	13.60	60
13	000	10			14.00	13.60	60
14	000	20			14.00	13.71	61
15	000	30			17.00	14.89	62
16	000	170			15.00	31.66	101
17	000	180			15.00	30.72	99
18	000	10			14.00	13.83	61
19	000	10			14.00	13.60	60

APPENDIX B

STREAM SAMPLE

LABORATORY REPORTS

Groundwater Monitoring
NPDES Effluent Monitoring
Waste Characterization

Edglo LABORATORIES INC.

2107 E. WASHINGTON BLVD. FORT WAYNE, INDIANA 46803

Phone (219) 424-1622

DATE RECEIVED 05/31/91

DATE REPORTED 06/12/91

TYPE SAMPLE CAT-1, CED-4 CED-6 Samples

RECEIVED FROM:

Gensic & Associates
311 ~~347~~ Airport North Office Park
Fort Wayne, IN 46825

ATTN: Michael Gensic

LAB REPORT NO 002

880-8827as

PARAMETER	CONCENTRATION	METHOD	TIME	ANALYST
CAT-1 - 05/31/91-7:27am				
T. Sus. Solids	136.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	55.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.52 "	EPA 365.1	06/01/91-11	LR
TKN*	3.0 "			
CED-4 - 05/31/91-7:18am				
T. Sus. Solids	84.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	22.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.45 "	EPA 365.1	06/01/91-11	LR
TKN*	2.0 "			
CED-6 - 05/31/91-7:12am				
T. Sus. Solids	86.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	43.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.43 "	EPA 365.1	06/01/91-11	LR
TKN*	1.0 "			

* = Total Kjeldahl Nitrogen

< = Less Than

RESPECTFULLY SUBMITTED
EDGLO LABS INC.
By Ed Duncan
JD

Edglo LABORATORIES INC.

2107 E. WASHINGTON BLVD. FORT WAYNE, INDIANA 46803

Phone (219) 424-1622

Groundwater Monitoring
NPDES Effluent Monitoring
Waste Characterization

DATE RECEIVED 05/31/91

DATE REPORTED 06/12/91

TYPE SAMPLE CED-7, LCD-1 LCD-2 Samples

RECEIVED FROM:

Gensic & Associates
311 ~~347~~ Airport North Office Park
Fort Wayne, IN 46825

ATTN: Michael Gensic

LAB REPORT NO 003

883-885/as

PARAMETER	CONCENTRATION	METHOD	TIME	ANALYST
CED-7 - 05/31/91-7:00am				
T. Sus. Solids	80.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	34.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.46 "	EPA 365.1	06/01/91-11	LR
TKN*	< 1.0 "			
LCD-1 - 05/31/91-7:50am				
T. Sus. Solids	48.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	39.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.69 "	EPA 365.1	06/01/91-11	LR
TKN*	2.0 "			
LCD-2 - 05/31/91-7:55am				
T. Sus. Solids	216.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	45.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	1.16 "	EPA 365.1	06/01/91-11	LR
TKN*	5.0 "			

* = Total Kjeldahl Nitrogen

< = Less Than

RESPECTFULLY SUBMITTED
EDGLO LABS INC.
By Ed Gensic JJ

Groundwater Monitoring
NPDES Effluent Monitoring
Waste Characterization

Edglo LABORATORIES INC.

2107 E. WASHINGTON BLVD. FORT WAYNE, INDIANA 46803

Phone (219) 424-1622

DATE RECEIVED 05/31/91

DATE REPORTED 06/12/91

TYPE SAMPLE RND-1, RND-3 RND-4 Samples

RECEIVED FROM:

Gensic & Associates
311 ~~347~~ Airport North Office Park
Fort Wayne, IN 46825

ATTN: Michael Gensic

LAB REPORT NO 004

886-888/as

PARAMETER — CONCENTRATION

RND-1 - 05/31/91-8:20am		METHOD	TIME	ANALYST
T. Sus. Solids	138.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	51.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.70 "	EPA 365.1	06/01/91-11	LR
TKN*	3.0 "			

RND-3 - 05/31/91-8:15am				
T. Sus. Solids	10.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	34.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.39 "	EPA 365.1	06/01/91-11	LR
TKN*	3.0 "			

RND-4 - 05/31/91-8:10am				
T. Sus. Solids	44.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	28.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.68 "	EPA 365.1	06/01/91-11	LR
TKN*	3.0 "			

* = Total Kjeldahl Nitrogen

< = Less Than

RESPECTFULLY SUBMITTED
EDGLO LABS INC.
By [illegible]
48

Edglo LABORATORIES INC.

2107 E. WASHINGTON BLVD. FORT WAYNE, INDIANA 46803

Phone (219) 424-1622

Groundwater Monitoring
NPDES Effluent Monitoring
Waste Characterization

DATE RECEIVED 05/31/91

DATE REPORTED 06/12/91

TYPE SAMPLE SHR-1, SHR-2 SHR-3 Samples

RECEIVED FROM:

Gensic & Associates
311 ~~347~~ Airport North Office Park
Fort Wayne, IN 46825

ATTN:

Michael Gensic

LAB REPORT NO 005

~~889-891/as~~

PARAMETER	CONCENTRATION	METHOD	TIME	ANALYST
SHR-1 - 05/31/91-7:40am				
T. Sus. Solids	940.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	121.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	1.69 "	EPA 365.1	06/01/91-11	LR
TKN*	4.0 "			
SHR-2 - 05/31/91-7:35am				
T. Sus. Solids	164.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	55.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.78 "	EPA 365.1	06/01/91-11	LR
TKN*	3.0 "			
SHR-3 - 05/31/91-7:30am				
T. Sus. Solids	48.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	38.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.40 "	EPA 365.1	06/01/91-11	LR
TKN*	4.0 "			

* = Total Kjeldahl Nitrogen

< = Less Than

RESPECTFULLY SUBMITTED
EDGLO LABS INC.
By Ed Sumac

Edglo LABORATORIES INC.

2107 E. WASHINGTON BLVD. FORT WAYNE, INDIANA 46803

Phone (219) 424-1622

Groundwater Monitoring
NPDES Effluent Monitoring
Waste Characterization

DATE RECEIVED 05/31/91

DATE REPORTED 06/12/91

TYPE SAMPLE SHR-R Sample

RECEIVED FROM:

Gensic & Associates
311 ~~247~~ Airport North Office Park
Fort Wayne, IN 46825

ATTN: Michael Gensic

LAB REPORT NO 006

8927as

PARAMETER	CONCENTRATION			
SHR-R - 05/31/91-7:07am		METHOD	TIME	ANALYST
T. Sus. Solids	60.0 mg/L	SM 209C 16	06/03/91-10	LR
COD	38.0 "	EPA 410.1	06/01/91-9	BB
Phosphorus	0.52 "	EPA 365.1	06/01/91-11	LR
TKN*	1.0 "			

* = Total Kjeldahl Nitrogen

< = Less Than

RESPECTFULLY SUBMITTED
EDGLO LABS INC.
By Ed Guerra

APPENDIX C

SIGNIFICANT NATURAL AREAS

CORRESPONDENCE

Division of Nature Preserves
402 W. Washington St., Rm. 267
Indianapolis, Indiana 46204
317-232-4052

September 20, 1991

Michael Gensic
Gensic & Associates
311 Airport North Office Park
Fort Wayne, IN 46825

Dear Mr. Gensic:

The following information is in response to your information request of September 4 regarding rare species and significant natural areas in the Tri-Lakes watershed.

The attached printout contains all current and historical records for state-listed plant and animal species. Arranged by lake, it includes the species scientific name, common name, status, location by section, specific location (if applicable) and date of record.

Round lake historically was considered a rich botanical site with a number of rare aquatic and wetland plant species, several of which have recent records. A portion of the northwest shore of Round Lake remains relatively unaltered and is considered a significant natural area. This area's wetland complex and associated lake bed should remain undisturbed. The enclosed map approximately delineates the area of concern.

Today Whitley County contains but three known significant natural area remnants. The area along the northwest shore of Round Lake thus represents a high priority for preservation in its natural state. Permanent protection of this area would be an ideal project to be undertaken by the local lake owners association, and would certainly seem to contribute to enhancing the lakes natural and scenic qualities.

You should note that cisco (Coregonus artedii), a fish species of special concern whose population is rapidly declining, formerly inhabited the Tri-Lakes complex. It was extirpated from Round and Shriner Lakes by 1975, and had disappeared from Cedar Lake by 1988. Disappearance of cisco is directly related to declining water quality. I have enclosed a recent (1989) report on the status and management of this species.

I have also enclosed a copy of a portion of a 1900 Report of the State Geologist that gives some historical background information on this lake complex. I think you will find this quite interesting.

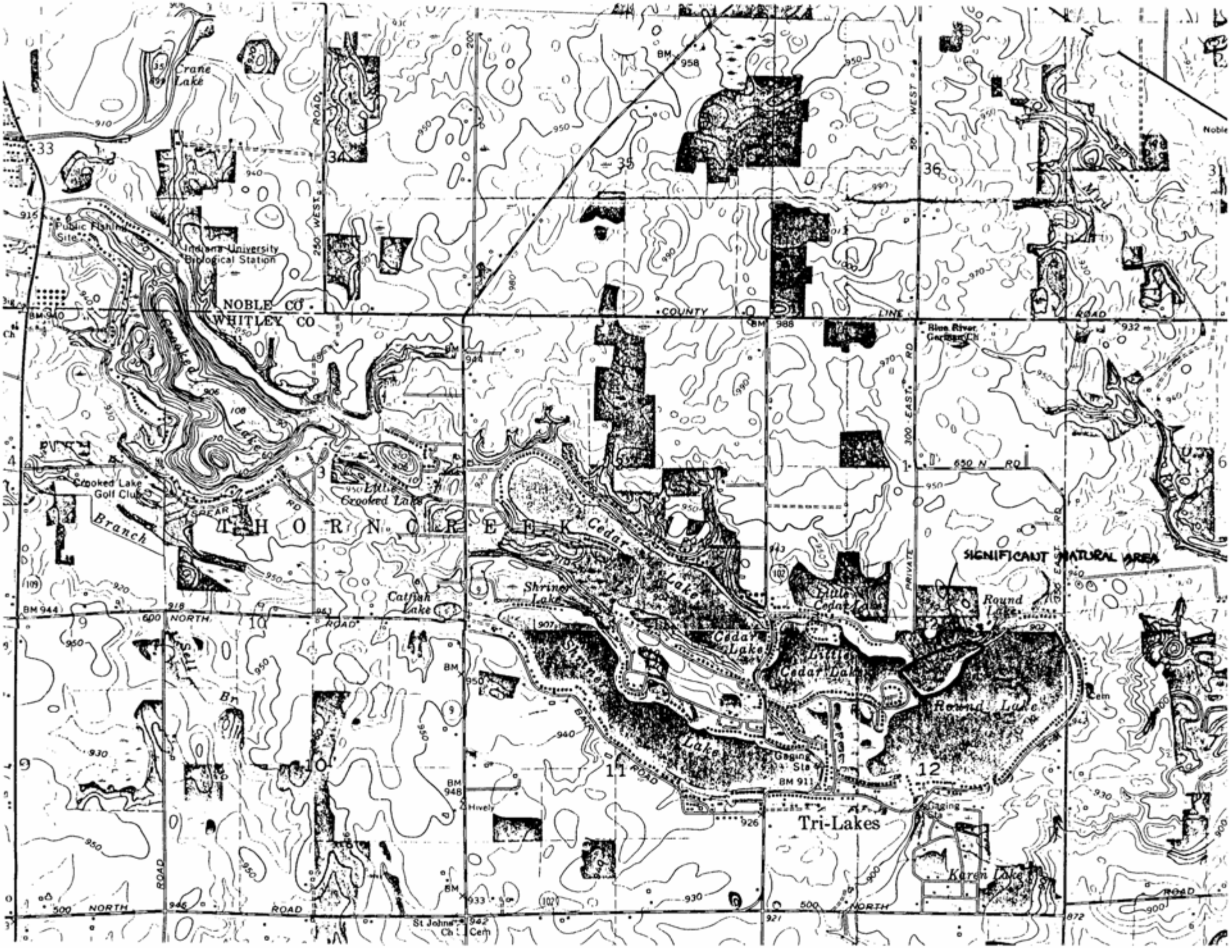
Since this request is in connection with the Indiana Lake Enhancement Program, our normal fee is waived.

Please do not hesitate to contact me if you have questions or require further information.

Sincerely,

Hank Huffman

Hank Huffman


Crane Lake
Public Fishing Site
Indiana University Biological Station
NOBLE CO
WHITLEY CO
Crooked Lake
Crooked Lake Golf Club
Little Crooked Lake
Branch
SPEAR RD
T H O R N C R E E K
Cedar Lake
Shriner Lake
Catfish Lake
Little Cedar Lake
Round Lake
SIGNIFICANT NATURAL AREA
Blue River German Ch
COUNTY LINE ROAD
650 N RD
250 WEST ROAD
300 EAST RD
PRIVATE
600 NORTH ROAD
500 NORTH ROAD
BAIR ROAD
Gaging Sta
BM 911
Tri-Lakes
Karen Lake
Hively
St Johns Ch Cem
Cem
Noble
33
34
35
36
9
10
11
12

17 SEP 1991

ENDANGERED, THREATENED, AND RARE SPECIES AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM THE TRI-LAKES WATERSHED IN WHITLEY COUNTY, INDIANA

Species Name	Common Name	State	Fed.	Townrange	Sec		Date
COLUMBIA CITY QUADRANGLE							
ROUND LAKE:							
BIDENS BECKII	BECK WATER-MARIGOLD	SE		032N009E	12	w side of lake	1933-08
ELEOCHARIS EQUISETOIDES	HORSE-TAIL SPIKERUSH	SE		032N010E	12	s shore of lake in shallow water	NODATE
ERIOCAULON SEPTANGULARE	PIPEWORT	SE		032N009E	12	shore of lake on sandy beach	1897-09
POTAMOGETON PRAELONGUS	WHITE-STEM PONDWEED	ST		032N010E	12	just off pier on nw side of lake	1985-07
POTAMOGETON RICHARDSONII	REDHEADGRASS	SE		032N009E	12	nw side of lake	1985-07
POTAMOGETON ROBBINSII	FLATLEAF PONDWEED	SE		032N009E	12	on marl beds in 2-4 feet of water	1933-09
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX		032N009E	12	w side of lake	1898-09
CORECONUS ARTEDII	CISCO OR LAKE HERRING	SSC					1955(?)
SHRINER LAKE:							
COREGONUS ARTEDII	CISCO OR LAKE HERRING	SSC		032N009E	11		1895 1955 (?)
MERRIAM QUADRANGLE							
CEDAR LAKE:							
COREGONUS ARTEDII	CISCO OR LAKE HERRING	SSC		032N009E	02	& S11	1974-08

SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list feet deep with a blue mud bottom. Then the marl increases in depth again, but at the same time becomes mucky, and the tests in water from three to 16 feet deep showed only muck. How far the marl runs back under the bank can only be conjectured. At the east end of the south side of the lake, no marl was found, the bottom being sandy. Several attempts to find marl under the sand failed. From (D) to (E) the bottom is hard sand or blue mud for about 50 feet out from shore or in from five to eight feet of water, then for 25 feet, or in water from five to 15 feet deep, the marl is over 16 feet thick and of good quality. For a short distance, at (F), 25 feet from shore, the marl is beyond 16 feet deep in three feet of water. But diagonally out from this in six feet of water only blue mud is found. At (G) this mud bottom extends up to the shore, while at (H) the top of the mud is marly. At (I) the marl is one foot deep at the shore and the same out in one foot or a little over of water. In three feet of water and from there out the bottom is sandy. At (J) tests in water from two to five feet deep showed marl everywhere to below 16 feet. Just north of this only muck was struck, then the marl sets in again, the bottom not being reached in from one foot to seven feet of water. In the northwest corner of the lake only muck was found. Then from (O) to (P) the marl occurs again, running from one foot deep in six inches of water to beyond reach of drill at the six-foot water-line. East of this it is shallow again, only one foot of marl being found in four feet of water. From (R) to (V) the marl is variable, often being absent close to shore and in places is not over one foot thick in 10 feet of water; but generally the marl is of good depth in six to 10 feet of water.

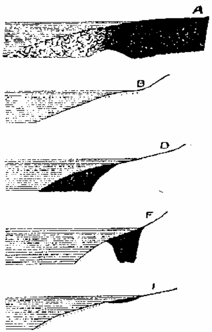


Fig. 35. Cross sections showing character of deposits at various points along shore of Blue River Lake, Whitley County, Ind.

The tests show that a large body of deep water marl occurs in the lake which may some day become available. The amount beneath shallow water is entirely too small to be of use at the present time.

FROM: THE LAKES OF
NO... AN...
THEIR ...
and
G.H. ASHLEY
REPORT OF THE
STATE GEOLOGIST

ROUND, CEDAR AND SHRINER LAKES.

Not a Workable Deposit.

These lakes lie close together in sections 1, 2, 11 and 12 (32 north, 9 east), Thorn Creek Township. They are connected by natural or artificial channels and hence will be treated under one general heading. The railway nearest them is the Eel River Division of the Wabash, distant about three and one-half miles to the southeast.

ROUND LAKE.

This lake, which receives its waters from the other two and from the drainage of the neighboring woods and fields, has a length of seven-eighths of a mile and a maximum width of one-half a mile. Its shores on the north and east are rather thickly wooded and rise 20 to 30 feet above the water. The south shore is lower and bordered with cultivated fields. A long bay filled with aquatic vegetation extends out to the northwest. From it an artificial channel connects Round Lake with Shriner Lake. The inlet from Cedar Lake is through a marsh grown up with cat-tail flag, *Typha latifolia* L., button-bush, *Cephalanthus occidentalis* L., swamp loosestrife, *Decodon verticillatus* (L.), and a variety of other aquatic plants, with occasional stretches of open water. It enters the north side of Round Lake, while the outlet, Thorn Creek, a tributary of Blue River, leaves the south side. Thorn Creek has been dredged for some distance, thus materially lowering the water area of the lake. As a result, a number of long points project out under the water and there is a large area of shallow water in the western third of its basin. "Lowering the lake five feet more will fill it with sand bars or even reduce it to a number of ponds. An extensive tract near the head of Thorn Creek, which five years ago was a swamp, is now under cultivation. Among the farmers of the neighborhood the practice is common of planting artichoke among the spatterdock where the lowering of the lake has exposed the land. In the fall this is turned over to hogs and their persistent rooting in the soft earth pulverizes and dries the soil most effectually."*

In October, 1900, a series of soundings, about 10 rods apart, beginning at the eastern edge of shallow water on the west side and running east, a little south of the middle of the lake, showed the depth of the water to be respectively: 18, 12, 28, 25, 26, 32 and 17

* Williamson, loc. cit., p. 153.

feet. Another line running across from (M) to (C) gave 17, 22, 38, 48, 51, 54, 57 and 32 feet.

The vegetation about Round Lake is very rank. The spatterdock, *Nuphar advena* R. Br., is very common, filling most of the bays and bordering the shores in many places. In the region of the second sounding, in the first series given above, a species of pondweed* was abundant, its fruiting head above the surface, its roots in the marl 12 feet below. Other species of pondweed are very common. Mr. C. C. Deam, of Bluffton, has found the reversed bladderwort, *Utricularia resupinata* Greene, growing along the western shore. The greater bladderwort, *U. vulgaris* L., is abundant, and eel grass, *Vallisneria spiralis* L., hornwort, *Ceratophyllum demersum* L., several species of water-millfoil, *Myriophyllum*, and the stiff white water crowfoot, *Batrachium tricophyllum* (Chaix.), cover the bottom of the more shallow portions of the lake.

The number of fishes in Round Lake is greater than in either of its neighbors, as is evinced by the following list of those taken in the three lakes in 1892 by Mr. Kirsch:

LIST OF FISHES KNOWN TO OCCUR IN ROUND, CEDAR AND SHRINER LAKES.†

1. *Lepisosteus osseus* (L.). Common Gar-pike.
2. *Ameiurus natalis* (Le S.). Yellow Cat.
3. *Ameiurus nebulosus* (Le S.). Common Bullhead.
4. *Catostomus teres* (Mitch.). Small-scaled Sucker; Black Sucker. Round Lake only.
5. *Erimyzon sucetta* (Lacépède). Chub Sucker; Sweet Sucker. Round Lake only.
6. *Minytrema melanops* (Raf.). Striped Sucker. Round Lake only.
7. *Pimephales notatus* (Raf.). Blunt-nosed Minnow.
8. *Notropis cayuga* Meek. Meek's Minnow.
9. *Notropis heterodon* (Cope). Variable-toothed Minnow.
10. *Notropis megalops* (Raf.). Common Shiner. Cedar and Round lakes.
11. *Hybopsis amblops* (Raf.). Silver Chub.
12. *Coregonus artedi sisco* (Jor.). Cisco. Shriner and Cedar lakes.
13. *Zygonectes notatus* (Raf.). Top Minnow. Shriner and Cedar lakes.

*This is the white-stemmed pondweed, *Potamogeton praelongus* Wulf. Another species very common in shallow water, where it formed thick beds on the bottom, was *P. robbinsii* Oakes. It grows but a foot or two high, and when the water is agitated the leaves spread out so that the whole plant resembles a fern. Both stem and leaves then wave gently to and fro in graceful motion.

† Where the species occurs in all three of the lakes no locality is given. Where in but one or two of them, they are mentioned specifically.

14. *Lucius vermiculatus* (Le S.). Grass Pike; Little Pickerel.
15. *Labidesthes sicculus* Cope. Brook Silverside; Smelt.
16. *Pomoxis sparoides* (Lacépède). Calico Bass.
17. *Chænobryttus gulosus* (Cuv. and Valenc.). Warmouth.
18. *Lepomis cyanellus* Raf. Green Sunfish. Round Lake only.
19. *Lepomis pallidus* (Mitch.). Blue-gill; Blue Sunfish.
20. *Lepomis euryorus* McKay. Broad-eared Sunfish. Cedar and Shriner lakes.
21. *Lepomis heros* (Baird and Girard). Chain-sided Sunfish. Round Lake only.
22. *Lepomis gibbosus* (L.). Common Sunfish.
23. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass.
24. *Etheostoma nigrum* (Raf.). Johnny Darter.
25. *Etheostoma eos* (Jor. and Cope.). Sunrise Darter.
26. *Etheostoma microperca* Jor. and Gilb. Least Darter. Round Lake only.
27. *Perca flavescens* (Mitch.) Ringed Perch; Yellow Perch.

MARL.—On the two bars indicated at (G) and (I) the water is shallow, a foot or less deep, and the marl from one to four feet in depth, while in two-and-a-half-foot water it thickens to seven feet. At the edge of deep water opposite (I) the marl had decreased to six feet and was underlain with a stiff, blue mud. In 12 feet of water it was six feet thick and underlain with gravel. Along the south shore between (J) and (K) the shallow water area, for the most part, overlies a good quality of marl 12+ feet in thickness. Near (M) in three feet of water it was 16+ feet thick but dark in color. At (A), across the lake, the same conditions exist, and at (B) there is too much muck to render the deposit of value. Good marl sets in again to the westward, and is everywhere 15+ feet thick in three feet of water. The shallow water area west of (C) widens greatly and is in most places, except within five rods of shore, underlain with marl below reach of 18-foot drill, though the water was seldom over 18 inches in depth. Close to shore the thickness of the marl is variable, running from three to 11 feet. The tests show that probably one-half of the area of the lake is underlain with marl. It is, however, variable in quality, much of that along the east end merging gradually into muck.

CEDAR LAKE.

This lake lies just northwest of Round Lake and empties into the latter through a broad, weedy channel. Cedar Lake is nearly divided into two unequal lobes, at the crossing of the north-south section line. The upper and larger lobe is about one mile long by one-quarter of a mile wide, with its main axis lying northwest and south-east. From its western side a short arm, now choked with vegetation, protrudes. The center of its basin shows a depth of water ranging from 45 to 79 feet. The lower lobe is but about one-third the size of the upper and is quite shallow. The shores of the entire lake are covered with underbrush, due to the fact that its level was raised by a dam at the same time that that of Shriner Lake was lowered. The shallow water area thus gained in the lower lobe is in part filled with muck and bears much aquatic vegetation, the spatterdock or yellow water lily being especially abundant. There are also many tree trunks and fallen limbs near the shore, which detract much from the original natural beauty of the lake.

MARL.—At most points around the lake the marl is shallow within the six-foot water line. Thus at (A) no marl is found in one or two feet of water, but in three feet or more of water the marl extends to below 16 feet. From (B) to (C) the marl is only six feet deep in seven feet of water, four feet in four feet of water, etc., the shallow water area being very narrow. From (D) to (E) the marl is deeper, being over 12 feet deep in four feet of water, and to below reach of drill at all depths beyond. From (E) to (G) some of the depths of marl found were as follows:

Water 4 feet—marl 8 inches to 3 feet.
Water 6 feet—marl 3 feet.
Water 7 feet—marl 7 feet.
Water 8 feet—marl 7 feet.

From (H) to (K) the marl is somewhat deeper, just about reaching 10 feet on the six-foot water line and extending below pole in all deeper water. At (L) only muck was found. Off the point at (M) the marl is over 15 feet deep in one foot of water at 75 feet from shore. From (N) to (P) in four and five feet of water, it runs from four to 10 feet in depth. Around most of the lake the area of shallow water is very narrow.

SHRINER LAKE.

This is one of the prettiest bodies of water in Indiana. Long and narrow, it lies like a priceless emerald of palest green, hidden and guarded by the surrounding hills. Its basin is in shape a deep trough or V, somewhat curved, one and one-quarter miles long by less than one-quarter mile wide in average width. In most places the water is shallow for only a few yards, or even feet from the shore line,

when the bottom suddenly descends at a sharp angle to a depth, in some places, of 65 or more feet. A small stream, dry most of the year, enters the lake at its southwestern corner; but springs are almost the entire source of water supply, hence the clearness and purity of its depths. Back from the water line the shores rise in low bluffs, which are covered with oak, maple and beech timber. A few sycamores and cotton-woods grow near the water's edge. Around the northern lobe of the lake the shores have, for the most part, been cleared, and are cultivated in places, within 75 feet of the water's edge.

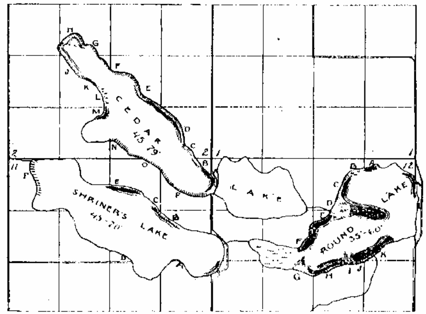


Fig. 36. Map of Cedar, Round and Shriner Lakes, Whitley County, Ind.

A number of soundings were taken in Shriner Lake on October 3d, 1900. In the southeast corner, at the boat landing, the water was six feet deep 20 feet from shore; 30 feet out it was 18 feet, and 100 feet out, 42 feet in depth. Forty rods west, on the south shore at (A), the shallow water area is less than 20 feet wide, then dips down at an angle greater than that of a steep house roof. The bottom, where it could be reached, was of a very tenacious blue mud, from which the auger, when sunk with difficulty about a foot, could hardly be removed. Ten feet from shore the water was eight feet deep. Three oar-strokes out it was 21 feet and 70 feet out was 32 feet. A line of soundings 50 feet apart from here across to (B) found the following depths: 45, 63, 65, 40, 27 and 8 feet, the last a boat's length from the north shore. Here the bottom was of marl six feet thick, with gravel beneath. At the bend, where the basin of the lake turns northward, a row of soundings from (C) to (D), 75 feet apart, resulted as follows: 48, 52, 50, 66, 60 and 34 feet. At this point the west shore is of gravel or sand, with but little vegetation. Sixty feet back from the water the wooded gravel hills rise 25 feet or more. Rowing 40 rods north along the gravelly west shore, another line, 10 oar-strokes apart, from east to west, showed 28, 51, 66, 62 and 26 feet. The shore on the east is here bordered by a marshy area, three to six rods wide, in which rushes, spatterdock and the green arrow-arum, *Peltandra virginica* (L.), flourish in profusion. The muck is here 12 feet deep in three-foot water, but at the water's edge the bottom is of a stiff blue mud. Just above this the lake narrows somewhat and then expands into a wider basin which comprises about one-quarter its area. Soundings near the center of this lobe showed the depth to range from 32 to 46 feet. Along the west shore of this basin the three-foot water line is underlain with 12 feet or more of muck, with gravel beneath.

In Shriner Lake and its neighbors, Round and Cedar lakes, are found growing in profusion many species of water-loving plants. Mr. C. C. Deam, of Bluffton, has taken there in August and September, the following species, all of which are aquatic, i. e., grow partly or wholly in the water:

LIST OF PLANTS GROWING IN ROUND, CEDAR AND SHRINER LAKES.

Typha latifolia L. Broad-leaved Cat-tail.
Potomogeton, four species. Pondweeds.
Sagittaria rigidi Pursh. Stiff Arrow-head.
Zizania aquatica L. Wild Rice.
Homalocenchrus oryzoides (L.). Rice Cut-grass.
Cyperus engelmanni Steud. Engelmann's Sedge.
Cyperus rivularis Kunth. River Sedge.
Dulichium arundinaceum (L.).
Eleocharis interstincta (Vahl.). Knotted Spike-rush.
Eleocharis mutata (L.). Quadrangular Spike-rush.
Scirpus americanus Pers. Chairmaker's Rush.
Scirpus atrovirens Muhl. Dark-green Bulrush.
Scirpus lacustris L. Great Bulrush; Mat Rush.
Scirpus lineatus Michx. Reddish Bulrush.
Rhynchospora glomerata (L.).
Cladium mariscoides (Muhl.). Twig-rush.
Carex lupuliformis Sartwell.

Carex comosa Boott. Bristly Sedge.
Eriocaulon septangulare With. Seven-angled Pipewort.
Pontederia cordata L. Pickerel-weed.
Juncus canadensis Gay. Canada Rush.
Rumex verticillatus L. Swamp Dock.
Polygonum incarnatum Ell. Slender Pink Smartweed.
Polygonum punctatum Ell. Water Smartweed.
Polygonum sagittatum L. Arrow-leaved Tear-thumb.
Brasenia purpurea (Michx.). Water-shield.
Nymphæa advena Soland. Large Yellow Pond Lily.
Castalia odorata (Dryand). White Water Lily.
Batrachium trichophyllum (Chaix.). Stiff White Water Crowfoot.
Decodon verticillatus (L.). Swamp Loosestrife.
Myriophyllum, one species. Water Millfoil.
Cicuta bulbifera L. Bulb-bearing Water-hemlock.
Cicuta maculata L. Water-hemlock.
Lycopus rubellus Moench. Water Hoarhound.
Mentha piperita L. Peppermint.
Gerardia paupercula (Gray). Small-flowered Gerardia.
Utricularia resupinata Greene. Reversed Bladderwort.
Utricularia vulgaris L. Greater Bladderwort.
Cephalanthus occidentalis L. Button-bush; Globe-flower.
Lobelia cardinalis L. Cardinal Flower.
Bidens beckii Torry. Water Marigold.
Bidens trichosperma (Michx.). Tall Tickseed Sunflower.

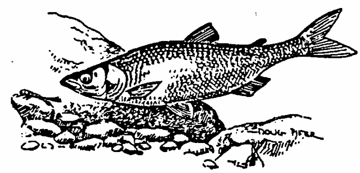
MARL.—On account of its deep shelving basin but little marl occurs around the margin of Shriner Lake. In the southeastern end near the boat landing there is a deposit six feet thick in two feet of water, and 12+ feet thick in six feet of water, but it is dark in color. Between (B) and (C) a better quality is found which is six feet thick in eight feet of water, but the bottom dips so rapidly that but little of it is available. Opposite (E), about half way the length of the east shore, there is an acre or two of shallow water, in which the marl is 15 feet thick in two-foot water and eight feet thick in one-foot water, with blue mud beneath. In the northwestern corner, at (F), there is a small area with marl bottom nine to 12 feet in thickness, in two to five feet of water. At all other points examined the bottom was of gravel, sand or muck.

There is, without doubt, quite an extensive deposit of marl beneath the deep water areas of Cedar and Round lakes, but that in Shriner Lake is evidently limited in extent. The deposit beneath the three lakes, considered as a whole, is not believed to be of sufficient importance to attract capital for cement making.

CISCO MANAGEMENT PLAN
(Exclusive of Lake Michigan)

Management History

The cisco, ***Coregonus artedii***, is a slender silver colored fish with a prominent adipose fin typically found on all members of the salmonid family. Its presence in northern Indiana marks the southernmost geographic distribution of the species. Cisco require cold, well-oxygenated water for survival, and unlike other trout species, cisco spawn readily in some Indiana lakes. They feed primarily on plankton (microscopic plants and animals) and typically reach a length of 10 to 14 inches.



The earliest recorded effort to manage cisco occurred in 1881 when a cisco gill netting season was established. Netting was abolished in 1901 but reinstated in 1937. Indiana phased out netting again in the mid-1970s. Declining cisco distribution and abundance caused by deteriorating water quality in several lakes, coupled with low public interest in netting were reasons for abolishing the use of gill nets. In the late 1970s and early 1980s, cisco were used as a forage source for lake trout stocked at three northern Indiana lakes.

Near the turn of the century, Indiana experimented with culturing cisco, white fish, and cisco x whitefish hybrids. Cisco production was reported between 1890 at a hatchery in Warren and 1914 at Tri-Lakes. Other reports indicate fishermen transported both cisco eggs and adult cisco to various lakes in northern Indiana. While it is generally agreed the cisco is the only native salmonid species found in Indiana waters, excluding Lake Michigan, their presence in some lakes might be attributed to early, poorly recorded stocking programs. The only verified successful introduction occurred at a gravel pit in Kosciusko County that was stocked with adult cisco. Attempts in the 1980s to establish cisco in Noble County's Gilbert Lake by stocking adults and later fry both appear to have been unsuccessful. Anglers currently harvest cisco by hook-and-line at Crooked Lake during the cisco spawning period in late fall. Unfortunately, due to depressed cisco abundance, harvest at several historical cisco lakes no longer occurs.

Supply

Cisco were probably present in many of Indiana's glacial formed lakes at one time. As the lakes aged and were altered by man, their physical and chemical characteristics changed, causing a disappearance of cisco from most lakes. Between 1900 and 1955, the number of lakes containing cisco decreased from 45 to 42. By 1975, the number of cisco lakes had dropped to 24 and many had only relict populations. Currently, cisco are believed to be present in 15 lakes but they are known to be common (one cisco or more per gill net lift) in only three lakes. Total acreage of cisco lakes today is less than 2,500 acres, down 70% from 1955. The three lakes where they are considered common cover only 391 acres.

Within the last ten years, cisco numbers have decreased sharply, even at Indiana's best cisco lakes. At Crooked Lake, annual harvest is down 82% from a peak of 5,500 cisco in 1980. During the 1970s, cisco were common in Gage, Lake-of-the-Woods and the Oliver Lake Chain. Today, only relict populations exist at these lakes, and in fact, cisco may be extinct at Lake-of-the-Woods. Large scale cisco die-offs typically occur late in the summer when the layer of cold well-oxygenated water suitable for cisco is depleted. Increased nutrient inputs each year cause this layer of cisco habitat to be reduced to the point where conditions for cisco survival are eliminated.

The primary reasons for the demise of the cisco and its habitat over the last thirty years appears to be intensive lakeside development and modern farming practices.

Demand

Interest in cisco fishing is negligible. In fact, even when netting was allowed an average of only 25 licenses were issued annually. At Crooked Lake, the most popular cisco lake, less than 5% of the annual fishing pressure is directed at cisco. But fishing pressure can be intense when cisco congregate during the late fall spawning period. Fishing pressure has been found to be directly related to cisco abundance. When cisco were abundant at Crooked Lake in 1980, about 1,000 angler hours were spent fishing for cisco during a two week period.

Analysis

Currently the demand for cisco is very low. Both cisco abundance and distribution have decreased dramatically in the last thirty years. The natural process of eutrophication may ultimately cause the demise of an environmentally sensitive species like cisco. Unfortunately, the rapid decline in cisco abundance in recent years illustrates how quickly water quality is changing. Unless future emphasis is placed on slowing eutrophication, cisco populations will no longer exist in Indiana. The demise of any species is discouraging. The demise of a species which occupies a unique niche, provides sport for fishermen, and serves as forage for larger more popular predator fish is especially disheartening. Future attempts to increase cisco abundance should focus on protecting water quality which will benefit all fish species.

Program Goal

Protect existing cisco habitat and increase cisco abundance.

Five Year Program Objectives

1. Develop programs with other agencies that will protect or improve water quality at the three primary cisco lakes by 1993.

2. Establish a self-sustaining cisco population at one lake with suitable water quality conditions by 1993.

Problems and Strategies

1. Cisco habitat is being lost through accelerated eutrophication.

- Evaluate the nutrient budget of the three primary cisco lakes and identify major sources of nutrient loading.
- Develop and support legislation and programs that curtail eutrophication.
- Discourage shoreline alterations at primary cisco lakes.
- Encourage weed control methods that limit nutrient recycling.

2. Cisco abundance at several lakes has not been monitored in a number of years and it is unknown if cisco habitat still exists.

- Conduct standardized netting surveys at lakes where current information on cisco abundance is lacking.
- Conduct periodic creel surveys at primary cisco lakes to measure harvest.
- Monitor cisco habitat by periodically conducting dissolved oxygen

and temperature profiles late in the summer and document the magnitude of all reported cisco die-offs.

3. Low level cisco abundance may be adversely affected by predator fish stocking programs.

- •Current rainbow trout stockings should continue. However, predator species should not be added nor should densities be increased at primary cisco lakes.

4. Most people are unaware of the cisco and its ability to serve as a biological indicator.

- •Inform the public of factors detrimental to cisco abundance and of efforts to preserve cisco habitat.

- •Provide current information on the status of cisco populations.

Plan period: January '89 through December '93.

INDIANA CISCO LAKES: POPULATION CHANGES

LAKE	COUNTY	ACRES	1955	1975	1988
Atwood	Lagrange	170	R	E	E
Big Long	Lagrange	366	R	E	E
Big Otter	Steuben	69	C	E	E
Cedar	Whitley	144	C	R	E
Clear	Steuben	800	C	R	R
Crooked	Whitley	206	C	C	C
Dallas	Lagrange	283	C	R	E
Eve	Lagrange	31	R	C	?
Failing	Steuben	23	C	C	?
Fish	Lagrange	100	C	E	E
Gage	Steuben	327	C	C	R
Gooseneck	Steuben	25	R	R	?
Gordy	Noble	31	C	R	R
Green	Steuben	24	R	E	E
Hackenburg	Lagrange	42	R	R	E
Hindman	Noble	13	R	R	E
Indian Village	Noble	12	R	E	E
James	Kosciusko	268	C	E	E
Lake James	Steuben	1034	C	R	E
Jimmerson	Steuben	283	C	R	E
Knapp	Noble	88	C	R	E
Lake-of-the-Woods	Lagrange	136	C	C	E
Lawrence	Marshall	59	C	C	C
Marsh	Steuben	56	C	E	E
Martin	Lagrange	26	C	C	R
McClish	Lagrange	35	C	C	R
Messick	Lagrange	68	R	R	E
Myers	Marshall	95	C	C	R
North Twin	Lagrange	135	C	R	E
Olin	Lagrange	103	C	C	R
Oliver	Lagrange	371	R	C	R
Oswego	Kosciusko	83	R	E	E
Round	Whitley	131	R	E	E
Sechrist	Kosciusko	99	C	E	E
Seven Sisters	Steuben	22	C	C	?
Shock	Kosciusko	32	C	E	E
Shriner	Whitley	120	C	E	E
Snow	Steuben	310	C	E	E
South Twin	Lagrange	116	C	C	C
Tippecanoe	Kosciusko	768	C	E	E
Wabee	Kosciusko	117	C	E	E
Witmer	Lagrange	204	R	E	E

C=COMMON R=RARE E=EXTINCT ?= NOT KNOWN

APPENDIX D

WETLANDS AND WATER QUALITY

Water Quality

School of Agriculture
School of Consumer and Family Sciences
Purdue University Cooperative Extension Service
West Lafayette, Indiana
USDA Cooperating

Wetlands and Water Quality

Brian K. Miller, Department of Forestry and Natural Resources

Wetlands once made up 25 percent of Indiana. Many of these 5.6 million acres were located in the fertile farmground of northern Indiana. Early in the 19th century, landowners began using open ditches and tiles to drain large areas of wetlands. They then converted the drained soil to agricultural production. Since then, nearly 86 percent of Indiana's wetlands have been drained or filled.

Wetlands are areas characterized by saturated or nearly saturated soils most of the year. Wetlands serve a number of important environmental functions. Location, soil type and surface and ground water movement determine which of the following functions a particular wetland may serve.

Flood Water Retention

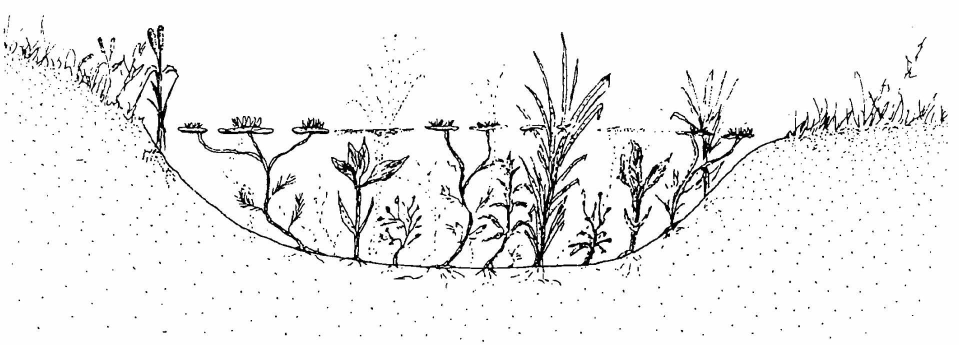
Usually located in depressions, wetlands receive surface runoff during storms. Water collects in these areas and contributes to stream flow when full or through ground water movement. Wetlands act as a holding area for large quantities of surface water which can be slowly released into a watershed. A one acre wetland, one foot deep, can hold approximately 330,000 gallons of water. When wetlands are removed, storm water runs directly into the watershed, increasing flooding.

Nutrient and Sediment Filtering

Often found in areas of intense agricultural production, wetlands play an important role in maintaining local water quality. Wetlands preserve water quality by removing nitrogen, phosphorus and pesticides from agricultural runoff.

Table 1. Common Wetland Aquatic Plants

Emergent	*Submergent*	*Floating*
Cattail	Pondweed	Duckweed
Spikerush	Naid	Watermeal
Smartweed	Watermilfoil	Water Hyacinth
Knotweed	Bladderwort	Water Lily
Arrowhead	Hydrilla	
Pickerelweed	Elodea	
	Coontail	



Chemicals and nutrients can enter a wetland through surface water and sediment, or through ground water. The major inorganic nutrients entering wetlands are nitrogen and phosphorus. In the wetland, nitrogen and phosphorus are removed from the surface water and transferred to the sediment, wetland plants or atmosphere. Some agricultural pesticides used in the Midwest can also be carried to the wetland through surface runoff.

Nitrates are lost from upland sites primarily through subsurface drainage. In the wetland, nitrates are absorbed by plants or converted (through an anaerobic process called denitrification) to nitrogen gas and lost to the atmosphere. Nitrate-N is efficiently removed from wetland surface waters by aquatic plants.

Ammonium-N enters wetlands primarily through surface runoff. In the wetland, ammonia is absorbed by plants or converted to nitrogen gas through volatilization. Nitrification can also occur, changing ammonia into nitrites and nitrates. The nitrate form of nitrogen is more readily removed from surface water by wetland plants than the ammonium form.

Phosphorus, organic nitrogen and some metals (iron or aluminum) usually attach to sediment and are carried by runoff to the wetland. By holding water, a wetland allows sediment and large particles to settle on the wetland bottom. The root systems of wetland plants then absorb nutrients from the sediment. Much like phosphorus, some pesticides also bind to sediment materials. Surface runoff carries the sediment materials to the wetlands and deposits them on the wetland bottom.

A particular wetland's function may change seasonally. During the growing season, in the summer and early fall, emergent and submerged aquatic plants (Table 1) take up large quantities of nutrients from water and sediment. Algae and floating plants absorb nutrients from surface water. These plants essentially convert the wetland into a "nutrient sink" by taking nutrients from the water and sediment and retaining them as plant material. By taking up and holding nutrients during the summer, wetlands decrease the possibility of contamination downstream (Figure 1).

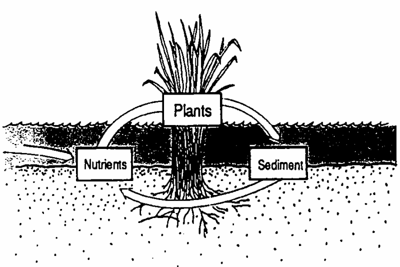


Figure 1. Sink

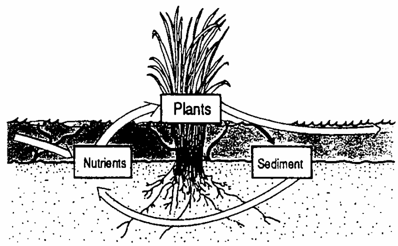


Figure 2. Source

When these plants die, a large portion of the nutrients return to the water and sediment from decaying plant material. During this period (in late fall and early spring), wetlands serve as a nutrient source when water flows from the wetlands to ecosystems downstream (Figure 2).

In most cases nutrients are recycled within the wetland. Emergent and submerged plants bring nutrients from the sediment into the water column, acting as "nutrients pumps." Algae and floating plants serve as "nutrient dumps" by taking nutrients from the water and depositing them back in the sediment when they die and settle on the bottom.

The cycle breaks when nutrients are removed from the wetland system, occurring when nutrient-rich water flows out of the wetland. The release of nitrogen gas to the atmosphere by denitrification, ammonia volatilization or possibly nitrification of ammonia also causes nutrients to be lost.

A wetland's natural filtering ability can become overloaded, disrupting the nutrient cycle. Steps can be taken to prevent overload by reducing nutrients and chemicals lost from agricultural fields.

Table 2. Benefits To Some Common Wildlife Species Provided By Wetland Vegetation

Type:	Plants around wetland edges	Emergent, submerged and floating vegetation in shallow water areas
Requirement:	Food and Cover	Food and Cover
	rabbits quail	waterfowl & broods
	pheasants song birds	muskrats mink otters fish insects
	waterfowl nest sites	song birds: red-winged blackbird,
		common yellow throat, marsh wren

Management practices to reduce runoff and leaching

The movement of nutrients and chemicals by sediment and surface runoff to wetlands can be reduced by conservation tillage and other common soil erosion control practices. These practices include: grass waterways, vegetative filterstrips, contouring and terracing. Incorporating fertilizers and chemicals reduces runoff by removing these substances from the runoff mixing zone.

Adjusting the timing and rate of fertilizer application to coincide with crop needs decreases nitrate leaching. Nitrate losses from animal waste can be reduced by timing of manure application, diverting feedlot runoff to grass filterstrips and limiting livestock's access to surface water.

Ground Water Exchange

Ground water and surface water are linked through wetlands. The following explains how wetlands impact surface water quality and also affect ground water quality and abundance.

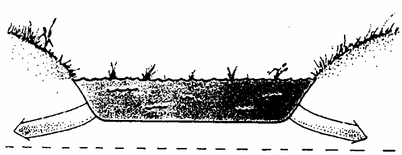


Figure 3. Water in wetlands, located above the water table, enters into ground water supplies if the underlying soils allow movement.

Wetlands with recharge capacity collect runoff water during storms and slowly release the water into ground water supplies (Figure 3). Wetlands therefore make positive contributions to soil moisture in agricultural settings. Without wetlands acting as a catch basin, damage from flooding and water erosion will likely increase.

In locations where the water table slopes away from the wetland, surface water in the wetland is relatively temporary. Because much of the volume may be contributed to recharge of ground water supplies. Draining these wetlands eliminates their recharge capacity and may adversely affect the surrounding soil moisture during dry periods.

Where the water table slopes toward the wetland, ground water discharges into the wetland (Figure 4). The water in this wetland is relatively permanent. Draining wetlands with ground water discharge capacity actually increases ground water discharge initially. However, over an extended period local water tables may be lowered.

Seasonal rainfall patterns may influence the direction of ground water flow within a wetland. During the spring, when water inputs are high, the wetland water level may be higher than the water table. At this time, the wetland acts as a point of recharge as water seeps from the wetland into the ground water. As the summer progresses, wetland water levels might drop to a level below the water table. Ground water then flows back into the wetland, which now serves as a point of ground water discharge (Figure 5).

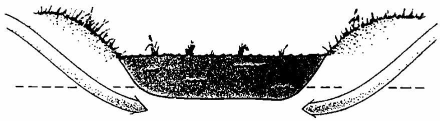


Figure 4. Wetlands located lower than the water table can receive ground water discharge.

Wildlife Protection

The appearance, character and function of wetlands vary depending on the depth of the water, length of flooding and characteristics of the surrounding land. The different types of wetlands provide a unique array of habitats for many species of wildlife (Table 2).

Wetlands which do not contain standing water all year still provide valuable wildlife habitat. The vegetation growing around the wetland edge serves as food and cover for many wildlife species, particularly during migration.

As an example, many small aquatic invertebrates are produced during the wet spring period. They survive the dry months by going into a dormant stage. These invertebrates hatch the following spring when the wetland contains water. The hatching usually coincides with migratory waterfowl's northward journey.

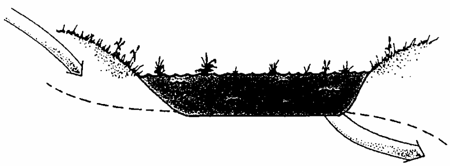


Figure 5. In many instances the same wetland may serve both functions. The water table slopes into a portion of the wetland and slopes away from the rest of the wetland. Where this "through flow" condition exists, wetlands are often referred to as semi-permanent.

Shallow water wetlands, which hold water throughout the year, contain emergent, submerged and floating vegetation throughout most of the marsh. The vegetation supports a variety of wildlife species (Table 2).

Submerged and emergent plants around the edges and shallow areas of deep water wetlands, provide food and cover for wildlife. In addition, the deep water area may furnish a suitable habitat for fish and often offers a source of recreation such as fishing, canoeing and swimming.

Preserving Wetlands

Wetlands play an important role in the freshwater system. They positively contribute to the quality of both surface and ground water supplies. In addition, wetlands provide habitat to many different species of wildlife.

In 1988, the U.S. Fish and Wildlife Service established a program in Indiana to assist landowners in restoring wetlands. For more information on the Wetland Restoration program contact: U.S. Fish and Wildlife Service, 718 N. Walnut Street, Bloomington, IN 47401, 812/334-4261.

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